



MIDWEST RESEARCH INSTITUTE
425 Volker Boulevard
Kansas City, Missouri 64110
Telephone (816) 753-7600

October 7, 1981

U.S. Environmental Protection Agency
5 EWHME
230 South Dearborn
Chicago, Illinois 60604



Attn: Mr. James Pankanin

Subject: Final Report, "Results of Analysis of Water Samples, Sludge Sample and Soil Samples for Polycyclic Aromatic Compounds (Hydrocarbons, Azaarenes, Phenols)," EPA Contract No. 68-02-2814, Assignment No. 21, MRI Project No. 4468-L(21).

Dear Mr. Pankanin:

Enclosed are three copies of the final report for the results of analysis of water, sludge and soil samples received from EPA Region V via the USGS. These samples were received between February 6, 1981 and March 13, 1981, and analyses were completed July 31, 1981.

This assignment completes our work for Contract No. 68-02-2814.

If you have any questions concerning this report, please do not hesitate to call me.

Sincerely,

MIDWEST RESEARCH INSTITUTE

A handwritten signature in black ink, appearing to read "Earl M. Hansen".
Earl M. Hansen, Head
Engineering Support Analysis Section

EMH:cmm

Enclosures

cc: Dr. Marc Hult
U.S. Geological Survey
702 Post Office Building
St. Paul, MN 55101
(1 copy of report)

Mr. Frank J. Biros
Hazardous Waste Task Force (E.N. 335)
Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460
(1 copy of report)

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CHAIN OF CUSTODY RECORD

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Project No.:	Samplers: (Signature) 
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Sample No. _____

Field No. #5
Sowing 3 1/2-3

~~797428~~



MIDWEST RESEARCH INSTITUTE
425 Volker Boulevard
Kansas City, Missouri 64110
Telephone (816) 753-7600

November 18, 1980

Ms. Melanie Toepfer
U.S. Environmental Protection Agency
5 EWHME
230 South Dearborn
Chicago, IL 60604

Dear Ms. Toepfer:

We are sending a copy of the extraction method we propose to utilize to analyze the soil samples from the St. Louis Park, Minnesota, site from Region V. It is Section 2, page 26ff, of the enclosed report. We have used this method exclusively for analysis of sludges, sediments and soils and found that it produces acceptable results (recoveries) for semivolatile priority pollutant compounds (acidics, base/ neutrals). This method is being utilized for analysis of soil samples from the Love Canal area by Southwest Research Institute. This method is also used for analysis of sludges currently by five contractors for the Effluent Guidelines Division of EPA. This method reflects state-of-the-art analysis of sludges and sediments for semivolatile priority pollutants.

We recently analyzed three soil samples from a waste site from EPA Region III according to the procedure in "An EPA Manual for Organics Analysis using GC/MS" (EPA-600/8-79-006), and found it to be satisfactory only for the base/neutral priority pollutants on the p.p. semivolatiles list. Recoveries for all the phenolic compounds were extremely low.

Basing our judgement on our own experience with these two methods, we recommend utilizing the "MRI Extraction Method", which we believe will give better results (recoveries) for most semivolatile compounds of the types of interest (polycyclic aromatic hydrocarbons, "coal tar bases", and phenols). The preference is due to the fact that this method utilizes extraction of the sample at two different pH values (pH=11, pH=2), which both separate the phenols from the base/neutral compounds and enhance their recovery. The analysis of those extracts is then accomplished by GC/MS.

007515

Ms. Melanie Toepfer
Page 2
November 18, 1980

If you have any questions regarding this method, please feel free to contact me.

Sincerely yours,

Evelyn E. Conrad.

Evelyn E. Conrad
Associate Chemist

EEC/slk

enclosure

007516

MRI  **REPORT**

RESULTS OF ANALYSIS OF WATER SAMPLES, SLUDGE SAMPLE AND
SOIL SAMPLES FOR POLYCYCLIC AROMATIC COMPOUNDS
(HYDROCARBONS, AZAARENES, PHENOLS)

FINAL REPORT

EPA Contract No. 68-02-2814, Assignment No. 21
MRI Project No. 4468-L(21)

October 7, 1981

For

U.S. Environmental Protection Agency
5 EWHME
230 South Dearborn
Chicago, Illinois 60604

Attn: Mr. James Pankanin

**RESULTS OF ANALYSIS OF WATER SAMPLES, SLUDGE SAMPLE AND
SOIL SAMPLES FOR POLYCYCLIC AROMATIC COMPOUNDS
(HYDROCARBONS, AZAARENES, PHENOLS)**

By

**Evelyn E. Conrad, Jill R. Guthrie and Earl M. Hansen
Midwest Research Institute
Kansas City, MO 64110**

FINAL REPORT

**EPA Contract No. 68-02-2814, Assignment No. 21
MRI Project No. 4468-L(21)**

October 7, 1981

For

**U.S. Environmental Protection Agency
5 EWRME
230 South Dearborn
Chicago, Illinois 60604**

Attn: Mr. James Panknin

PREFACE

Water and soil samples taken from sites in Minnesota which are potentially contaminated with coal tars were analyzed for polycyclic aromatic compounds (PAC). These analyses were part of a collaborative study by the U.S. EPA Region V and the USGS. The analyses were carried out by widely accepted, state-of-the-art techniques with slight modifications for improved or extended range.

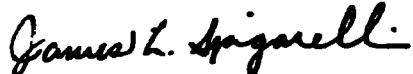
This report was prepared by Evelyn E. Conrad, with assistance from Jill R. Guthrie and Earl M. Hansen in fulfillment of the requirements of Contract No. 68-02-2814, Assignment No. 21, MRI Project No. 4468-L(21).

Task leaders who were responsible for the analyses of the samples were Ms. Jill Guthrie and Ms. Janine Niels.

Questions regarding this report should be directed to the primary author. The telephone number is (816) 753-7600.

Approved for:

MIDWEST RESEARCH INSTITUTE



James L. Spigarelli, Director
Analytical Chemistry Department

October 7, 1981

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SUMMARY

The objective of this task was the analysis of 50 water samples, 1 sludge sample and 9 soil samples for polycyclic aromatic compounds (PAC), polycyclic aromatic hydrocarbons (PAH), azaarenes, and phenolic compounds. The water and soil samples were analyzed for extractable PAC by solvent extraction, concentration of the extracts, and analysis of the extracts by gas chromatography/mass spectrometry (GC/MS). Those water samples in which no PAC were found by GC/MS were analyzed by liquid chromatography with ultraviolet and fluorescence detection for the 16 PAH specified in EPA Method 610. Eight water samples were analyzed for purgeable halocarbons (VOAs) by EPA Method 624 and for purgeable aromatics using a modification of EPA Method 602.

The results of the analyses of the water samples varied greatly. In 10 water samples virtually no analytes were detected (0 to 4 ng/liter total PAC). Eleven water samples contained less than 300 ng/liter PAC. Thirteen water samples contained 300 to 1,000 ng/liter total PAC and 14 water samples contained 1,000 to 10,000 ng/liter (1 to 10 µg/liter) total PAC. Three water samples contained more than 100 µg/liter total PAC. One water sample contained more than 3 g/liter (3,000 mg/liter) total PAC. The sludge sample contained the equivalent of 120 g/liter of PAC.

The soil samples also varied greatly in their PAC content. Two samples were virtually free of PAC (1.1 µg/g or less). Another sample contained less than 20 µg/g of total PAC. Two soil samples contained less than 250 µg/g of total PAC; three samples contained 4,000 to 6,000 µg/g total PAC; and one contained about 40,000 µg/g of total PAC.

SECTION 1

INTRODUCTION

This report gives the results of analysis of 50 water samples, 1 sludge sample, and 9 soil samples for polycyclic aromatic compounds (PAC) (hydrocarbons, azaarenes and phenols). Those water samples in which no PAC were detected by GC/MS were analyzed for 16 specific polycyclic aromatic hydrocarbons (PAH) specified in EPA Method 610. A limited number of the water samples were also analyzed for volatile priority pollutants (VOAs). The analytes required for each matrix are listed in Table 1. The samples were sent by the Region V office of the United States Environmental Protection Agency (via the U.S. Geological Survey in Minneapolis, Minnesota, who are engaging in a collaborative study) and were received and inventoried on various dates between February 6, 1981 and March 13, 1981. Copies of the chain-of-custody forms are enclosed in the Appendix. At the request of the USGS, Sample Nos. 810516, 810521, 810522 and 810534 were replaced by resampled specimens 810593, 810591, 810592, and 810589, respectively. Sample No. 810510 was resampled as 810594 and both were analyzed. Presented in this report are descriptions of the analytical procedures, the results of the analyses, and a discussion of the results of analysis with conclusions and recommendations. Attached to this report are computer-recovered mass spectra (MS) all the polycyclic aromatic hydrocarbon (PAH) or VOA priority pollutants, phenols and azaarenes found in the samples during GC/MS analysis, as well as mass spectra of the corresponding standard compounds. The mass spectra of other compounds identified in the samples are also included (Figures 1 through 277). Reconstructed ion chromatograms (RICs) of the samples analyzed by the purge-and-trap methods are also included. RICs of the acid and base/neutral extracts of the water and soil samples have not been included because of the large numbers (approximately 100) of chromatograms involved. All of the data pertaining to this project has been retained and is available on request.

TABLE 1. ANALYTES SOUGHT DURING DIFFERENT METHODS OF ANALYSIS

Matrix	Method	Analytes specifically sought
Water, soil	GC/MS	Naphthalene Acenaphthene Acenaphthylene Fluorene Phenanthrene Fluoranthene Pyrene Chrysene Benzo[a]pyrene Benzo[k]fluoranthene Dibenz[a,h]anthracene Benzo[g,h,i]perylene Acridine Carbazole Quinoline Indole Phenol o-Cresol 2,4-Dimethylphenol 2,4,6-Trichlorophenol
Water	HPLC	Naphthalene Acenaphthylene Acenaphthene Fluorene Phenanthrene Anthracene Fluoranthene Pyrene Benz[a]anthracene Chrysene Benzo[b]fluoranthene Benzo[k]fluoranthene Benzo[a]pyrene Dibenz[a,h]anthracene Benzo[g,h,i]perylene Indeno[1,2,3-c,d]pyrene

(continued)

TABLE 1 (concluded)

Matrix	Method	Analytes specifically sought
Water	"VOA" method for purgeables	Chloromethane Dichlorodifluoromethane Chloroethane Bromomethane Chloroethene Dichloromethane Trichlorofluoromethane 1,1-Dichloroethene 1,1-Dichloroethane <u>1,2-trans-Dichloroethene</u> Trichloromethane 1,2-Dichloroethane 1,1,1-Trichloroethane Tetrachloromethane Bromodichloromethane 1,2-Dichloropropane 1,3-Dichloropropene Trichloroethene Dibromochloromethane Benzene 1,1,2-Trichloroethane Tribromomethane 1,1,2,2-Tetrachloroethane Tetrachloroethene Methylbenzene Chlorobenzene Ethylbenzene
Water	Purgeable aromatics	Benzene Methylbenzene Ethylbenzene 1,2-Dimethylbenzene Naphthalene Monomethyl naphthalenes Identifiable light aromatic hydrocarbons

SECTION 2

SAMPLE PREPARATION AND ANALYSIS

WATER SAMPLE AND SLUDGE SAMPLE

GC/MS Analysis

Water samples were prepared for analysis for extractable compounds by the procedures specified in EPA Method 625. All water samples except the fortified quality assurance samples were spiked with 100 µg/liter (100 ppb) of each of the surrogate compounds pentafluorophenol and decafluorobiphenyl. The samples were sequentially extracted at pH = 11-12 and then at pH = 2 with methylene chloride in liquid-liquid extractors and the methylene chloride extracts were concentrated to 1 ml in Kuderna-Danish (KD) apparatus. These concentrated extracts were analyzed by gas chromatography/mass spectrometry (GC/MS) using the following conditions:

GC/MS Conditions for Base/Neutral Extracts of Water, Soil and Spiked Water Samples--

Column: 1.8 m x 2 mm ID glass, packed with 1% SP-2250 on 100/120 mesh Supelcoport
Temperature Program: 50°C for 4 min then 10°C/min to 260°C. Hold at 260°C past the elution time for benzo[g,h,i]perylene
Injector Temperature: 225°C
GC/MS Interface Temperature: 275°C
Carrier Gas: Helium at 30 ml/min

GC/MS Conditions for Acid Extracts of Soil, Water and Spiked Water Samples--

Column: 1.8 m x 2 mm ID glass, packed with 1% SP-1240-DA on 100/120 mesh Supelcoport
Temperature Program: 85°C for 4 min, then 10°C/min to 200°C
Injector Temperature: 185°C
GC/MS Interface Temperature: 275°C
Carrier Gas: Helium at 30 ml/min

The extract of Sample No. 810593 (USGS No. W13) was strongly colored. A preliminary analysis by GC/FID showed many large peaks suspected of being PAC. Therefore, this extract was diluted by 1:5000 before being analyzed by GC/MS.

Sample No. 810529 (USGS No. W-23A bottom) was a viscous brown material containing a very small proportion of water. It could not be treated as a

water sample. The sample was mixed well by hand and then a 1-g sample of it was weighed and dissolved in 60 ml of methylene chloride. This solution was spiked with 50 µg each of pentafluorophenol and decafluorobiphenyl and was extracted with 50 ml of 1 N NaOH to isolate phenolic compounds. The basic aqueous solution was acidified to pH = 1-2 and back extracted twice with 50 ml of methylene chloride. The volume of this methylene chloride solution was adjusted to 100 ml and it was then analyzed by GC/MS for phenolic compounds. The base/neutral extract in methylene chloride was washed twice with a small amount of water and the volume was adjusted to 100 ml and it was analyzed by GC/MS for base/neutral PACs.

The GC/MS conditions used for the analysis of the base/neutral or acid fractions of this sample extract were the same as those cited above for the base/neutral or acid extracts, respectively, of the water samples.

After the analysis of the extracts, 10 water samples were spiked with PAC analytes. The spiked samples were extracted, concentrated and analyzed the same way as the unspiked samples except that no surrogate compounds were added to the spiked samples.

Analysis of Water Samples for PAH by Liquid Chromatography

In some water samples, no PAC were detected during GC/MS analysis of the extracts. At the request of Dr. Marc Hult of the USGS, the base/neutral extracts of these samples were taken for analysis for PAH by liquid chromatography (LC) essentially as described in EPA Method 610. This LC method, which utilizes UV absorption and fluorescence detectors is more sensitive for PAH than GC/MS but is subject to more interferences and lacks the confirmation-of-identity specificity for analytes which is provided by mass spectrometric detection.

For the LC analysis it was necessary that the samples be in acetonitrile solution. Therefore, the methylene chloride extracts were subjected to a solvent exchange. The volume of the methylene chloride extract was reduced to 0.5 ml in a gentle stream of purified nitrogen at room temperature. Five milliliters of acetonitrile were added and the volume of acetonitrile solution was reduced to 2 ml in a stream of nitrogen at room temperature. An autoinjector for the LC was used to inject 20 µl of each sample and also appropriate standards of PAH in acetonitrile solution into the LC system.

The LC analyses were carried out with the following conditions:

Column: 250 mm L x 2.6 mm ID, Perkin-Elmer HC-ODS-Sil-X

Solvent Program: 40% acetonitrile, 60% water for 5 min, then linear program to 100% acetonitrile in 25 min. Return to initial conditions and hold for 10 min.

Flow Rate: 0.5 ml/min

Detection: UV absorbance at 254 nm and fluorescence (excitation at 280 nm and emission at 389 nm)

Analysis of Water Samples for Volatile Priority Pollutants and Purgeable Aromatic Compounds

At the request of Dr. Marc Hult, USGS, a few selected water samples which were suspected of containing volatile contaminants were analyzed for purgeable aromatic hydrocarbons. The purge and trap procedure as described in EPA Method 602 was used. The GC column used was the same as that cited in EPA Method 602. The temperature program described in Method 602 was extended:

Column: 6 ft x 2 mm glass, packed with 5% SP-1200/1.75% Bentone 34 on 100/120 mesh Supelcoport

Temperature Program: 50°C for 2 min, then 6°C/min to 170°C and hold 8 min

Carrier Gas: Helium at 30 ml/min

Detector: Varian/MAT CH4 Mass Spectrometer coupled with Incos 23 Data System

These conditions provided timely elution of aromatic hydrocarbons from benzene to the monomethyl naphthalenes with satisfactory resolution of most of the hydrocarbons of interest (example: good resolution of ethyl benzene and the three xylenes, see Figure 182). However, it was soon observed through use of the computerized MS output that in the GC effluent from some water samples there were halocarbon compounds which were not resolved from the purgeable aromatic hydrocarbons. For example, benzene is not resolved from dichloroethylene. Therefore, a number of samples were analyzed by the purge-and-trap method especially suited to volatile halocarbons (EPA Method 624).

Unfortunately, the gas chromatographic conditions used to resolve and analyze for the halocarbon priority pollutants (VOAs), such as dichloroethylene (see below) cannot be used for most purgeable aromatic hydrocarbons; ethylbenzene can be eluted and measured with the "VOA" system but not xylenes, naphthalenes, etc.

The GC conditions for volatile organic priority pollutants (VOAs), mostly halocarbons were:

Column: 8 ft x 2 mm ID glass column packed with 0.2% Carbowax 1500 on 80/100 mesh Carbopack C

Temperature Program: 35°C for 3 min then 10°C/min to 175°C and hold for 10 min

Carrier Gas: Helium at 30 ml/min

Detector: Varian/MAT CH4 Mass Spectrometer coupled with Incos 23 Data System

Some samples were analyzed by both methods and some by the VOA protocol only.

The quantities of the analytes found by the "VOA" method of analysis were determined by comparison with standards of the same compounds of known concentration. The quantitative measurements of the analytes found by the "purgeable aromatics" method were made by comparing the area of the analyte peak in the

ion chromatogram with the area of the peak of one of three compounds, 1,2-dimethylbenzene, naphthalene, or 1-methylnaphthalene, in a quantitative standard purged and treated exactly like a sample. The response of naphthalene standard was used for a standard for naphthalene and 1-methylnaphthalene was used for a standard for the monomethylnaphthalenes in the samples. The 1,2-dimethylbenzene standard was used for all the other light aromatic compounds quantitated by this method.

PREPARATION AND ANALYSIS OF SOIL SAMPLES

Fifty grams of each soil sample were weighed into the cup of a Soxhlet extraction apparatus and extracted overnight with methanol. The methanol was removed and the sample was then Soxhlet extracted with methylene chloride. The two extracts were combined and concentrated in Kuderna-Danish apparatus. Some difficulties (bumping, slow concentration) were encountered during this concentration step apparently because of a high concentration of extractables and for most samples, the K-D distillation was stopped before the solvent volumes had been reduced to the customary 1 or 2 ml. The extract of Sample No. 810555 was reduced to 1 ml in the K-D apparatus.

The concentrated extracts of the other samples contained either methylene chloride solution, methylene chloride solution plus precipitated solids, or methylene chloride solution plus (wet) methanol solution. The extract (1 ml) of Sample No. 810555 was taken directly for GC/MS analysis. It was analyzed twice, by the conditions described earlier for base/neutral extracts and by the conditions described earlier for acid extracts of water samples. The other extracts which did not contain a methanol phase were diluted with methylene chloride to dissolve any solids and the volumes were adjusted to a known volume (the nearest convenient volume was used). Aliquots of these solutions were first surveyed by GC/FID to estimate the concentration of analytes. Aliquots of these solutions were then appropriately diluted with methylene chloride and analyzed by GC/MS. These extracts were also analyzed under the two sets of conditions described for base/neutral and for acid extracts of water samples.

The two layers of the two phase extracts were separated. The organic layers were dried with sodium sulfate and the volumes were adjusted to the nearest convenient volume. Aliquots of these solutions were first surveyed by GC/FID to estimate the concentration of the analytes. Aliquots of these solutions were then appropriately diluted with methylene chloride and analyzed by GC/MS using the conditions described earlier for base/neutral extracts from water samples. The aqueous layers were acidified (to pH = 2) and extracted three times with 10 ml of methylene chloride. The methylene chloride solutions were dried with sodium sulfate, the volumes were adjusted to an even number of milliliters, and the solutions were analyzed by GC/MS using the conditions described for acid extracts of water samples.

SECTION 3

DISCUSSION

WATER SAMPLES BY GC/MS

The extracts of the water samples were first analyzed by GC/MS as described above. The results of the analyses are summarized in Table 2. In 34 of the 50 water samples analyzed by this method, no polycyclic aromatic compounds were detected (see Table 9 for estimated detection limits of PAC by GC/MS). Five samples (Sample Nos. 810506, 810507, 810517, 810538, and 810589) were found to contain PAC at levels below 1 µg/liter each. Six samples (Nos. 810508, 810510, 810524, 810532, 810549, and 810592) were found to contain PAC at levels up to 10 µg/liter each. Three samples (Nos. 810526, 810527, and 810590) were found to contain PAC at levels up to 300 µg/liter each. One water Sample No. 810593 was found to contain a total of more than 3 million µg/liter of PAC. Another sample, No. 810529, more like petroleum than water, contained PAC in the milligrams per gram range (the equivalent of many grams of PAC per liter).

Recovery of analytes from spiked water samples (Table 3) and recovery of surrogate compounds from the water samples (Table 4) are overall acceptable and reproducible. Only phenol, of the compounds tested, gave somewhat lower and variable results. The surrogate compounds were not observable in Sample Nos. 810529 and 810593 because these samples were of necessity, diluted several thousand-fold before GC/MS analysis.

The recoveries of analytes from spiked Sample No. 810527 are less satisfactory than the recoveries from the other spiked samples. The original water sample contained high concentrations of polycyclic aromatic compounds and it was spiked at higher levels than the other water samples. If the actual water samples in the two sample jars were not initially exactly identical in PAC concentration, that could lead to erroneous recovery data. Also, slight variation in analyte recovery during the extraction step could cause the same effect.

Mass spectra of all analytes measured in the water samples by GC/MS as well as mass spectra of compounds in standards are included with this report (Figures 1 through 89). The comparability of mass spectra, together with coincidental retention times for samples and standards are regarded as absolute confirmation of identity of the analytes.

ANALYSIS OF WATER SAMPLES BY LC

Thirty-four samples and four duplicate samples were analyzed by LC as described above after the solvent had been exchanged to acetonitrile. The results of the analyses are given in Table 5. The results were extremely varied.

TABLE 2, PART 1. RESULTS OF ANALYSIS OF WATER SAMPLES BY GC/MS
FOR EXTRACTABLE POLYCYCLIC AROMATIC COMPOUNDS IN $\mu\text{g}/\ell$

MRI No.	Sample USGS No.	Compound(s)	Concentration ($\mu\text{g}/\ell$)
810506	W-1	Fluoranthene Pyrene	0.24 0.21
810507	W-2	Fluoranthene Pyrene	0.41 0.28
810508	W-101	Naphthalene Acenaphthene	4.7 0.84
810509	W-116	N.D. ^a	
810510	W-117	Acenaphthene	2.5
810511	W-124	N.D.	
810511D	(duplicate analysis)	N.D.	
810512	W-133	N.D.	
810513	SLP No. 5	N.D.	
810514	SLP No. 6	N.D.	
810515	Minnesota Rubber	N.D.	
810517	Meadowbrook Golf Course	Phenanthrene Fluoranthene Pyrene Carbazole	0.3 0.4 0.3 0.5
810518	Prudential Well No. 2	N.D.	
810519	Beckman Produce	N.D.	
810520	N.W. Hospital No. 2	B/N extract lost No phenols detected	
810520D	(duplicate analysis)	N.D.	
810523	SLP No. 5	N.D.	

(continued)

TABLE 2, PART 1 (continued)

MRI No.	Sample USGS No.	Compound(s)	Concentration ($\mu\text{g}/\ell$)
810524	SLP No. 6	Phenol	2.4
810525	Minnesota Rubber	N.D.	
810526	NAT LEAD	Naphthalene Acenaphthene Carbazole	137 19 4.2
810526D	(duplicate analysis)	Naphthalene Acenaphthene Carbazole	135 21 4.3
810527	W-23A	Naphthalene Acenaphthene Acenaphthylene Fluorene Phenanthrone Fluoranthene Pyrene Chrysene Benzo[a]pyrene Benzo[k]fluoranthene Carbazole	130 29 17 29 49 30 14 5 9 5 11
810528	Old SLP No. 1	N.D.	
810530	L. Harriet No. 2	N.D.	
810531	Daytons No. 3	N.D.	
810532	W-38	Fluoranthene Pyrene	2.1 1.4
810533	Eitel Hospital	N.D.	
810535	Norris Milk	N.D.	
810536	Richfield No. 1	N.D.	
810537	Hopkins No. 1	N.D.	
810538	Hopkins No. 3	Acenaphthene	0.4

(continued)

TABLE 2, PART 1 (continued)

MRI No.	Sample USGS No.	Compound(s)	Concentration ($\mu\text{g/l}$)
810539	MTKA No. 11	N.D.	
810540	MTKA No. 12	N.D.	
810541	MTKA No. 13	N.D.	
810542	MTKA No. 14	N.D.	
810542D	(duplicate analysis)	N.D.	
810543	SLP No. 4	N.D.	
810544	SLP No. 5	N.D.	
810545	SLP No. 6	N.D.	
810546	SLP No. 8	N.D.	
810547	SLP No. 10	N.D.	
810548	SLP No. 11	N.D.	
810549	SLP No. 15	Acenaphthene Acenaphthylene Fluorene Phenanthrene Pyrene Fluoranthene	1.5 1.6 1.7 0.8 0.4 0.8
810550	Edina No. 2	N.D.	
810551	Edina No. 6	N.D.	
810552	Edina No. 16	N.D.	
810552D	(duplicate analysis)	N.D.	
810553	Weldwood Nursing Home	N.D.	
810554	Honeywell No. 1	N.D.	

(continued)

TABLE 2, PART 1 (concluded)

MRI No.	Sample USGS No.	Compound(s)	Concentration ($\mu\text{g/l}$)
810589	Flame Industries	Acenaphthene Fluorene Fluoranthene Pyrene	0.8 0.7 0.5 0.4
810590	P-14	Naphthalene Acenaphthene Fluorene Phenanthrene Carbazole	50 160 80 30 260
810591	SLP No. 4	N.D.	
810591D	(duplicate analysis)	N.D.	
810592	SLP No. 15	Acenaphthene Acenaphthylene Fluorene Phenanthrene Fluoranthene Pyrene	3.0 2.0 3.0 0.7 1.0 0.9
810594	W-117	Acenaphthene	3.0
Blank 2/25		N.D.	
Blank 3/2		N.D.	
Blank 3/5		N.D.	
Blank 3/9		N.D.	
Blank 3/12		N.D.	
Blank 3/16		N.D.	
810593	W-13	Naphthalene Acenaphthene Fluorene Phenanthrene Fluoranthene Pyrene Chrysene	1,400,000 100,000 200,000 800,000 600,000 300,000 200,000

a N.D. means none detected. See Table 9 for estimated detection limits.

TABLE 2, PART 2. RESULTS OF ANALYSIS OF SLUDGE SAMPLE BY GC/MS FOR
EXTRACTABLE POLYCYCLIC AROMATIC COMPOUNDS IN mg/g

MRI No.	Sample USGS No.	Compound(s)	Concentration
			(mg/g)
810529	W-23A bottom	Naphthalene	8.8
		Acenaphthene	5.8
		Acenaphthylene	1.7
		Fluorene	7.9
		Phenanthrene	27.0
		Fluoranthene	21.0
		Pyrene	14.0
		Chrysene	6.8
		Benzo[a]pyrene	5.9
		Benzo[k]fluoranthene	17.0
		Benzo[g,h,i]perylene	3.9
		Carbazole	0.54
		Acridine	0.72

TABLE 3. RECOVERIES (%) OF POLYCYCLIC AROMATIC COMPOUNDS IN SPIKED WATER SAMPLES ANALYZED BY GC/MS

Compound	Sample No.									
	810508	810510	810514	810514D	810524	810530	810532	810540	810550	810527
Naphthalene	61	70	60	59	58	76	56	55	50	14
Acenaphthene	67	76	66	65	66	64	57	57	55	32
Acenaphthylene	39	43	46	47	50	48	44	45	43	43
Fluorene	72	80	68	66	66	64	58	58	58	0
Phenanthrene	88	110	80	84	96	87	84	74	69	13
Fluoranthene	104	116	96	94	94	92	78	82	78	8
Pyrene	76	88	72	72	72	68	60	64	60	0
Chrysene	96	130	76	84	88	84	81	74	67	52
Benzo[a]pyrene	72	84	64	64	64	60	60	56	48	20
Benzo[k]fluoranthene ^a	-	-	-	-	-	-	-	-	-	-
Dibenz[a,h]anthracene	92	120	82	81	87	86	84	73	64	66
Benzo[g,h,i]perylene	85	116	77	78	82	80	86	68	60	62
Carbazole	84	94	74	74	74	70	66	66	64	52
Indole	80	88	68	68	72	66	64	62	60	64
Quinoline	84	90	78	76	78	74	70	70	66	72
Acridine	76	80	66	68	68	66	62	62	60	64
Phenol	12	34	10	22	26	64	16	16	10	66
2,4,6-Trichlorophenol	62	88	92	104	100	140	114	120	80	150

a An accurate quantitation of benzo[k]fluoranthene recovery in the spiked samples could not be made due to the interference of co-eluting benzo[b]fluoranthene which was contained in the spiking solution.

TABLE 4. RECOVERY (%) OF SURROGATE COMPOUNDS
FROM WATER SAMPLES DURING GC/MS ANALYSIS

Sample No.	% Recovery	
	Decafluorobiphenyl	Pentafluorophenol
810506	73	24
810507	38	0
810508	49	82
810509	56	0
810510	42	23
810511	36	0
810511D	34	12
810512	53	88
810513	22	99
810514	60	86
810515	89	100
810517	56	62
810518	57	79
810519	76	0
810520	No B/N sample	93
810520D	76	120
810523	59	120
810524	65	130
810525	69	120
810526	110	170
810526D	87	160
810527	110	99
810528	78	22
810529	0	0
810530	96	11
810531	62	83
810532	81	40
810533	59	12
810535	112	18
810536	99	49
810537	62	100
810538	120	34
810539	90	20
810540	110	28
810541	62	14
810542	59	22
810542D	51	32
810543	53	93
810544	56	15
810545	43	36

(continued)

TABLE 4. (concluded)

Sample No.	% Recovery	
	Decafluorobiphenyl	Pentafluorophenol
810546	71	39
810547	78	22
810548	52	30
810549	73	36
810550	42	20
810551	75	25
810552	98	97
810552D	52	86
810553	86	No acid sample
810554	50	78
810589	78	110
810590	63	130
810591	61	82
810591D	49	130
810592	77	130
810593	0	0
810594	45	27

TABLE 5. RESULTS OF ANALYSIS OF SELECTED WATER SAMPLES FOR POLYCYCLIC AROMATIC HYDROCARBONS BY HPLC (CONCENTRATION GIVEN IN ng/l)^a

Compound	Sample No.										
	810511	810511D ^b	810512	810513	810514	810515	810518 ^c	810519 ^c	810520D	810523	810524
Naphthalene			120 u				200 u	120 u			
Acenaphthylene			200 u		200 u	200 u	300 u	300 u			200 u
Acenaphthene									260 u		540 u
Fluorene	33 u		16 u			33 u	33 u	16 u			16 u
Phenanthrene	250 u		120 u				39 u	39 u	4 u		
Anthracene ^a											
Fluoranthene ^a	180 u		180 u	3							
Pyrene ^a	19		33	6		16	> 1,000 u ^e	> 1,000 u ^e			
Benz[a]anthracene	10		11	2	1	< 1			100 u		
Chrysene	12		22	5	10	< 1			> 1,000 u ^e		
Benzo[b]fluoranthene	7		6	1				120 u			1
Benzo[k]fluoranthene	3		3	1	< 1			330 u			1
Benzo[a]pyrene	3		4	1	27						2
Dibenz[a,h]anthracene	6			12	-						
Benzo[g,h,i]perylene	7		13								
Indeno[1,2,3-c,d]pyrene	6		6	4	38						

(continued)

TABLE 5. (continued)

Compound	Sample No.										
	810528	810530	810531	810533	810535	810536	810537	810539	810540	810541	810542
Naphthalene	12,000 u										
Acenaphthylene	17,000 u										
Acenaphthene	8,000 u										
Fluorene	16 u	16,000 u		33 u		15 u					
Phenanthrene		13,000 u		26 u							
Anthracene ^a											
Fluoranthene ^a		14,000 u									
Pyrene ^a		14,000 u		90 u							
Benz[a]anthracene	1		< 1		2	< 1			< 1	10	
Chrysene	100 u	17,000 u	< 1		17				4	8	10
Benzo[b]fluoranthene	5	2,000 u	2		2	< 1					
Benzo[k]fluoranthene	6		< 1		1		1			< 10	
Benzo[a]pyrene	6	4,000	2		4		1			< 10	
Dibenz[a,h]anthracene	120	92,000			6				280		
Benzo[g,h,i]perylene		98,000	25		26						
Indeno[1,2,3-c,d]pyrene	3		8		8						

(continued)

TABLE 5. (continued)

Compound	Sample No.													
	810543	810544	810545	810546	810547	810548	810550	810551	810552	810552D	810553	810554		
Naphthalene	< 10 u													
Acenaphthylene						400 u	200 u							
Acenaphthene							1,100 u	100 u	540 u	260 u	260 u	2,600		
Fluorene						180 u		33 u	33 u	33 u	33 u	110	15	
Phenanthrene						9 u								
Anthracene ^a														
Fluoranthene ^a														
Pyrene ^a						26								
Benz[a]anthracene						12	< 1	< 1						
Chrysene			4			8	3	6						
Benzo[b]fluoranthene	1					< 1								
Benzo[k]fluoranthene	1					< 1		< 1						
Benzo[a]pyrene	1					< 1								
Dibenz[a,h]anthracene														
Benzo[g,h,i]perylene														
Indeno[1,2,3-c,d]pyrene														

(continued)

TABLE 5. (concluded)

Compound	Sample No.							
	810591	810591D ^e	Solvent blank 2/25/81	Solvent blank 3/2/81	Solvent blank 3/5/81	Solvent blank 3/9/81	Solvent blank 3/12/81	Solvent blank 3/16/81
Naphthalene								
Acenaphthylene								
Acenaphthene	260 u	500 u						
Fluorene	90 u	70 u					19	
Phenanthrene	66 u	65 u	20 u					23
Anthracene^a								
Fluoranthene^a								
Pyrene ^a								
Benz[a]anthracene								
Chrysene	35							
Benzo[b]fluoranthene								
Benzo[k]fluoranthene								
Benzo[a]pyrene	11			8				
Dibenz[a,h]anthracene	370							
Benzo[g,h,i]perylene	900 u							
Indeno[1,2,3-c,d]pyrene								

a Very strong fluorescence and UV absorption peaks of unknown origin interfered with or completely prevented measurement of anthracene, fluoranthene and pyrene in chromatograms of all samples and blanks.

b Entire chromatogram obscured by background interferences.

c Fluorescence detection hampered by interfering peaks

d "u" indicates results are from UV detection. Other results are from fluorescence detection.

e Medium - size peak but off-scale due to artifact peak, therefore not measureable.

No PAH were detected in seven samples (Nos. 810524, 810528, 810537, 810539, 810540, 810544, and 810546) and nearly none in six more (Nos. 810523, 810536, 810542D, 810543, 810545, and 810554). (See Table 10 for estimated detection limits of the PAH by LC.) In 14 samples, (Nos. 810511, 810512, 810513, 810514, 810515, 810520D, 810530, 810533, 810535, 810541, 810542, 810550, 810552, and 810552D) several PAH at concentrations up to 300 ng/liter each were measured. Concentrations of some PAH at concentrations of about 1,000 ng/liter were found in eight samples (Nos. 810518, 810519, 810525, 810547, 810548, 810551, 810591, and 810591D). Sample No. 810553 was found to contain 2,600 ng/liter of ace-naphthene.

Sample No. 810531 was found to have many peaks giving strong UV and fluorescence signals. As in the case of the other samples, identification of the analytes in the liquid chromatogram was based primarily on the retention times of the compounds eluted and secondly on the ratio of the UV absorbance and fluorescence signals. The amounts of PAH analytes identified in Sample No. 810531 by applying these methods are higher than those found by GC/MS analysis of the sample. The quantities of PAH analytes calculated, if actually present, would have been readily detected by the GC/MS method. We must conclude that the results from the LC analysis of No. 810531 are subject to chromatographic interference from compounds which coelute with the 16 PAH's specified in the method.

Other difficulties were encountered during the LC analysis of the samples. An intense UV and fluorescence peak occurred in the extracts of all sample and solvent blanks. This signal always completely obscured the retention time region of anthracene and usually obscured the retention time regions for fluoranthene and pyrene as well. In some samples, the artifact peak was less intense and a peak attributed to fluoranthene or pyrene could be observed. In view of the difficulties in making accurate time or intensity measurements near a strong artifact peak, all the values reported for fluoranthene and pyrene from the LC analysis must be viewed with caution. No anthracene peaks were ever observable. Since the artifact peak was present in solvent blanks also, we attribute it to a solvent impurity which was concentrated during the sample preparation.

Some individual sample extracts gave chromatograms which were partly (Nos. 810518 and 810519) or completely (No. 810511D) obscured by substances of unknown origin. For Sample No. 810511D, no fluorescence signal was recorded (however, data for Sample No. 810511 are available, see Table 5).

Analysis of the water sample extracts by LC was carried out in accordance with the protocol described in EPA Method 610 and the analytical results are considered acceptable with the exceptions detailed above. However, it must be remembered that this method of analyzing for polycyclic aromatic hydrocarbons does not provide for unequivocal identification of any of the analytes.

ANALYSIS OF WATERS FOR VOLATILES

Analyses of a few water samples for purgeable organic compounds yielded a surprising abundance of measurable analytes. These are presented in Tables 6 and 7. The samples were selected after the GC/MS analyses were completed.

TABLE 6. RESULTS OF ANALYSIS OF SELECTED WATER SAMPLES
FOR VOLATILE PRIORITY POLLUTANTS BY GC/MS
(VOA METHOD) in $\mu\text{g/l}$

MRI No.	Sample USGS No.	Compound(s)	$\mu\text{g/l}$
810506	Well W-1	benzene	3
810507	Well W-2	tetrachloroethene	56
810508	Well W-101	chloroethene (vinyl chloride) 1,2-trans-dichloroethene trichloroethene benzene	72 2,900 1,100 120
810510	W-117	chloroethene (vinyl chloride) 1,2-trans-dichloroethene trichloroethene benzene tetrachloroethene	69 570 1,100 10 790
810517	Meadowbrook Golf Course	dichloromethane	20
810526	Nat. Lead.	trichloroethene benzene methylbenzene ethylbenzene	20 690 16 200
810527	W-23A	benzene	4
810590	P-14	benzene methylbenzene ethylbenzene	1,900 270 50

TABLE 7. RESULTS OF ANALYSIS OF SELECTED WATER SAMPLES FOR PURGEABLE AROMATIC COMPOUNDS BY GC/MS IN $\mu\text{g/l}$

Sample		Compounds identified	Concentration $\mu\text{g/l}$
MRI No.	USGS No.		
810508	Well W-101	dichloroethene benzene trichloroethene 3-methyloctane	see Table 6 see Table 6 see Table 6 not quantified
810510	W-117	dichloroethene trichloroethene tetrachloroethene 3-methyloctane trimethylheptane 2,3-dihydro-1-H-indene	see Table 6 see Table 6 see Table 6 not quantified not quantified 30
810526	Nat. Lead.	benzene toluene ethylbenzene dimethylbenzene isomer dimethylbenzene isomer 1,2-dimethylbenzene isopropylbenzene ethylmethylbenzene isomer ethylmethylbenzene isomer ethylmethylbenzene isomer trimethylbenzene isomer trimethylbenzene isomer 2,3-dihydro-1-H-indene 1-H-indene methyldihydroindene isomer 1-methyl-1-H-indene naphthalene	see Table 6 5 140 30 30 60 5 10 10 10 10 20 160 100 not quantified 10 5
810590	P-14	benzene toluene ethylbenzene dimethylbenzene isomer dimethylbenzene isomer 1,2-dimethylbenzene ethylmethylbenzene isomer ethylmethylbenzene isomer ethylmethylbenzene isomer trimethylbenzene isomer	430 160 50 90 230 180 10 100 25 60

(continued)

TABLE 7 (concluded)

<u>Sample</u>		<u>Concentration</u> <u>µg/l</u>	
<u>MRI No.</u>	<u>USGS No.</u>	<u>Compounds identified</u>	
810527	W-23A	trimethylbenzene isomer	150
		2,3-dihydro-1-H-indene	300
		benzofuran	not quantified
		1-methyl-2,3-dihydroindene	not quantified
		1-H-indene	270
		tetramethylbenzene isomer	not quantified
		methyldihydroindene isomer	not quantified
		methyldihydroindene isomer	not quantified
		methylbenzofuran isomer	not quantified
		1-methyl-1-H-indene	80
		naphthalene	400
		2-methylnaphthalene	240
		1-methylnaphthalene	190
		naphthalene	30
		2-methylnaphthalene	40
		1-methylnaphthalene	40

Water samples contaminated with extractable PAC were chosen for purgeable analysis, based on the results of the GC/MS analyses and guided by suggestions from Dr. Marc Hult that we analyze some of the contaminated samples for volatile organics. Analysis of the selected water samples by GC/MS using the "VOA" method or the "purgeable aromatics" method, (EPA Method 624 or 602) showed that these samples were all contaminated with relatively volatile aromatic or halogenated compounds or both. The large number of compounds found by this method of analysis do not duplicate those on the list of "extractable" analytes with the sole exception of naphthalene.

Sample Nos. 810508 and 810510 contained high concentrations of halocarbons, most notably vinyl chloride. Sample No. 810506 was found to contain a relatively low concentration of benzene. Sample No. 810527 contained a few micrograms/liter of benzene, naphthalene, and the monomethylnaphthalene isomers. Tetrachloroethylene (56 µg/liter) was found in Sample No. 810507 and a small amount of dichloromethane (20 µg/liter) was found in Sample No. 810517.

Sample No. 810526 contained a small amount (20 µg/liter) of trichloroethene and at least 17 volatile aromatic hydrocarbons in quantities of 5 to 160 µg/liter (see Table 7). Sample No. 810590 contained high concentrations (> 100 µg/liter) of benzene, toluene, xylene isomers, indene and indene derivatives and naphthalene as well as numerous other volatile aromatic compounds such as benzofuran, alkylated benzenes, etc. (see Table 7). Such mixtures of aromatic compounds are known to occur in coal tars and likely originated from coal tar contact or contamination of the water samples by coal tar wastes.

ANALYTICAL RESULTS FOR SOIL SAMPLES

The results of the analysis of soil samples for extractable polynuclear aromatic compounds are summarized in Table 8. Two of the soil samples (Nos. 810555 and 810556) were uncontaminated with polycyclic aromatic compounds, i.e., they contained 1 µg or less of PAC. Sample No. 810562 contained eight PAC at less than 10 µg/g of each and Sample Nos. 810561 and 810563 contained 7 and 13 compounds, respectively, at concentrations ranging from 10 to 100 µg/g each. Sample Nos. 810557, 810558, 810559, and 810560 contained hundreds or thousands of micrograms/gram of several PACs. Sample No. 810559 is very heavily contaminated. It appears to contain at least 40,000 µg/g of total PAC.

Azaarenes (carbazole and/or acridine) were found in seven of the nine samples. An unspecified cresol isomer was identified and measured in only one sample.

There is no single well-established method for extraction of PAC from soil samples with reproducibly high recovery. We used an extraction procedure which has been shown to give high recovery of PAC from other soil samples. However, the variable chemical and physical properties of soils can greatly influence the recovery of PAC from the samples. Consequently, the quantitative measurements of the PAC in these soil samples should be taken as minimum values.

TABLE 8. RESULTS OF ANALYSIS OF SOIL SAMPLES BY GC/MS FOR EXTRACTABLE
POLYCYCLIC AROMATIC COMPOUNDS IN $\mu\text{g/g}$

Compound	Sample No.								
	810555	810556	810557	810558	810559	810560	810561	810562	810563
Naphthalene	ND	ND	330	930	8,400	3,100	38.0	8.0	73.0
Acenaphthene	ND	ND	340	450	2,100	410	20.0	2.0	8.0
Acenaphthylene	ND	ND	ND	ND	ND	11	20.0	ND	8.0
Fluorene	ND	ND	290	460	3,400	460	30.0	1.0	11.0
Phenanthrene	.050	ND	940	1,300	17,000	1,200	90.0	4.0	33.0
Fluoranthene	.025	ND	800	860	3,700	750	30.0	2.0	14.0
Pyrene	.017	ND	750	390	1,700	350	26.0	1.0	12.0
Chrysene	ND	ND	190	210	1,300	160	ND	.5	6.0
Benzo[a]pyrene	.009	ND	100	57	ND	73	ND	ND	7.0
Benzo[k]fluoranthene	ND	ND	400	250	460	240	ND	ND	16.0
Dibenz[a,h]anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo[g,h,i]perylene	ND	ND	43	ND	ND	22	ND	ND	.5
Carbazole	ND	ND	56	81	5,300	150	ND	.4	.2
Indole	ND	ND	ND	ND	ND	ND	ND	ND	ND
Quinoline	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acridine	ND	1.1	36	48	ND	37	ND	ND	1.0
2,4-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenol	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4,6-Trichlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND
<i>o</i> -Cresol	ND	ND	ND	ND	ND	29	ND	ND	ND

Note: All values in $\mu\text{g/g}$ of soil, as received.

SECTION 4

CONCLUSIONS AND RECOMMENDATIONS

During the analysis of water samples by multiple methods, quantitative data for the same compound in the same water sample were sometimes obtained by two or more methods. Where two methods of analysis were used, there is often agreement only within an order of magnitude. We consider the solvent extraction GC/MS determination of PACs the most reliable of the methods used. Documentation by other workers and the results of the quality control samples (recoveries from spiked samples, recoveries of surrogates, agreement of duplicate analyses) for the current set of analyses indicate that recovery and reproducibility of this method are good. Also, of course, the analyte peaks are unequivocally identified. The analysis of extracts of water samples for PAH by LC with UV and fluorescence detection, while it may give lower detection limits for PAH in "clean" samples than the GC/MS method, is subject to interferences at the detector and relies heavily on retention time for identification of the analytes. For highly contaminated samples, it becomes increasingly difficult to assign peaks to PAH analytes with confidence. However, the greatest usefulness of this analytical method is in the analysis of "clean" samples. Because of the great sensitivity, when no UV or fluorescence responses are observed, it can be concluded with confidence that no analytes are present above their detection limits (see Table 10).

The "VOA" or purge-and-trap method for analyzing for halocarbons, benzene, toluene and ethylbenzene is well-established and considered reliable. External standards were used to quantify the compounds reported and their identity was confirmed by inspection of their mass spectra.

The "purgeable aromatics" method for the light aromatic hydrocarbons, while yielding much information, is not a well-established or validated method for the quantitative analysis of the compounds reported. External standards for quantification of the analytes were available only for 1,2-dimethylbenzene, naphthalene, and 1-methylnaphthalene. Quantification of the other compounds reported is based on comparison of the analyte response of single standard of the most similar analyte (see text) and is expected to be reliable within a factor of three. Identification of these analytes by inspection of their mass spectra is considered reliable although isomers cannot be distinguished when retention times of authentic compounds are not known.

The results of the purge-and-trap analyses of selected water samples offer two points to note.

1. There were quantities of many different "light" aromatic compounds in some of the water samples. This may have special implications for those concerned with water quality or hydrologic phenomena.

TABLE 9. ESTIMATED DETECTION LIMITS FOR
POLYCYCLIC AROMATIC COMPOUNDS IN
WATER BY GC/MS ANALYSIS^a

Compound	Detection limit as ng/l
Naphthalene	200
Acenaphthene	300
Acenaphthylene	250
Fluorene	350
Phenanthrene	250
Fluoranthene	250
Pyrene	300
Chrysene	500
Benzo[a]pyrene	800
Benzo[k]fluoranthene	800
Dibenz[a,h]anthracene	1,400
Benzo[g,h,i]perylene	1,300
Carbazole	750
Indole	650
Quinoline	850
Acridine	400
Phenol	300
2,4,6-Trichlorophenol	400
2,4-Dimethylphenol	400
<u>o</u> -Cresol	400

^a Based on responses of standards run over
a 4-month period.

TABLE 10. ESTIMATED DETECTION LIMITS FOR
POLYCYCLIC AROMATIC HYDROCARBONS IN
WATER BY HPLC ANALYSIS^a

Compound	Detection limit as ng/l
Naphthalene	150 (UV)
Acenaphthylene	300 (UV)
Acenaphthene	200 (UV)
Fluorene	20 (UV)
Phenanthrene	10 (UV)
Anthracene	5 (UV)
Fluoranthene	2
Pyrene	3
Benz[a]anthracene	1
Chrysene	4
Benzo[b]fluoranthene	< 2
Benzo[k]fluoranthene	< 1
Benzo[a]pyrene	1
Dibenz[a,h]anthracene	8
Benzo[g,h,i]perylene	10
Indeno[1,2,3-c,d]pyrene	5

a Based on recently run standards. Detection limit(s) observed or projected to 2X the average noise level.

2. The method used to analyze for the eight aromatic compounds may be the best method currently available and should be considered for future analyses of this kind.

A considerable body of literature about analytical methods and results has been accumulated for extractable aromatic compounds. This information has usually emphasized determination of the polycyclic (two to five rings) aromatic hydrocarbons because they are fairly stable, easy to detect, and are thought to present a human health hazard. Interest in volatile halocarbons such as chloroethenes in water has similarly led to general acceptance of the purge-and-trap method of analysis for these compounds. Benzene, toluene, and ethylbenzene are amenable to this method of analysis and are often determined simultaneously with the halocarbons using a GC/MS detection system resulting in an abundance of analytical data about these three compounds in water samples also.

So far as we know, the occurrence in water samples of aromatic compounds heavier (less volatile) than toluene and lighter (more volatile) than naphthalene has not been extensively studied. Solvent extraction of these compounds (alkylated benzenes, benzofurans, indene derivatives, etc.) is feasible but they are very susceptible to loss by volatilization during solvent concentration procedures.

The purge-and-trap GC technique described above when coupled with a mass spectrometer has enabled us to analyze for a large number of these compounds in some of the present set of water samples. The GC conditions described allow chromatographic resolution of a large number of these light aromatic compounds such as the three xylenes, the three ethylmethylbenzenes, etc., and the use of a computerized mass spectrometer for a detector allows MS resolution, identification and quantification of many more compounds. We believe that future use of this method, or improvements of it, can generate a great deal of qualitative and quantitative information about the presence of light aromatic hydrocarbons in water samples.

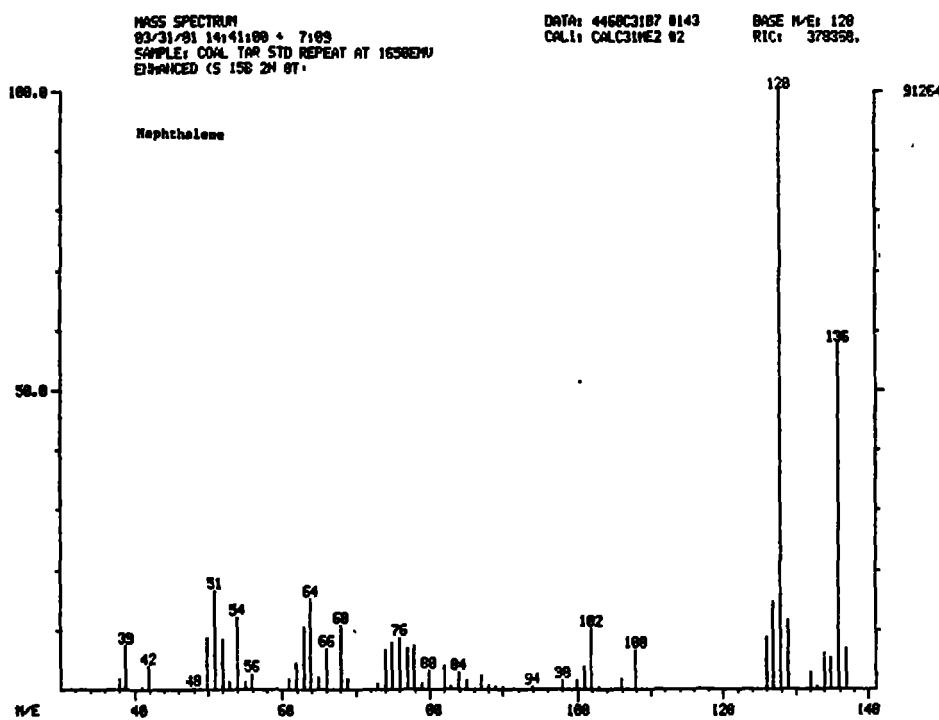


Figure 1. Mass spectrum of naphthalene in standard.

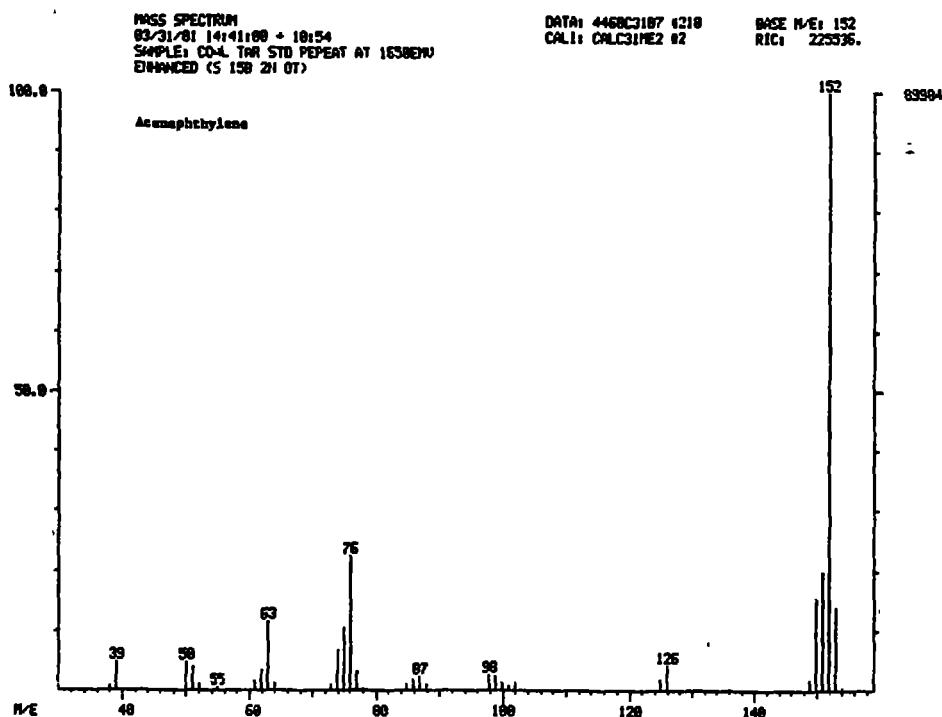


Figure 2. Mass spectrum of acenaphthylene in standard.

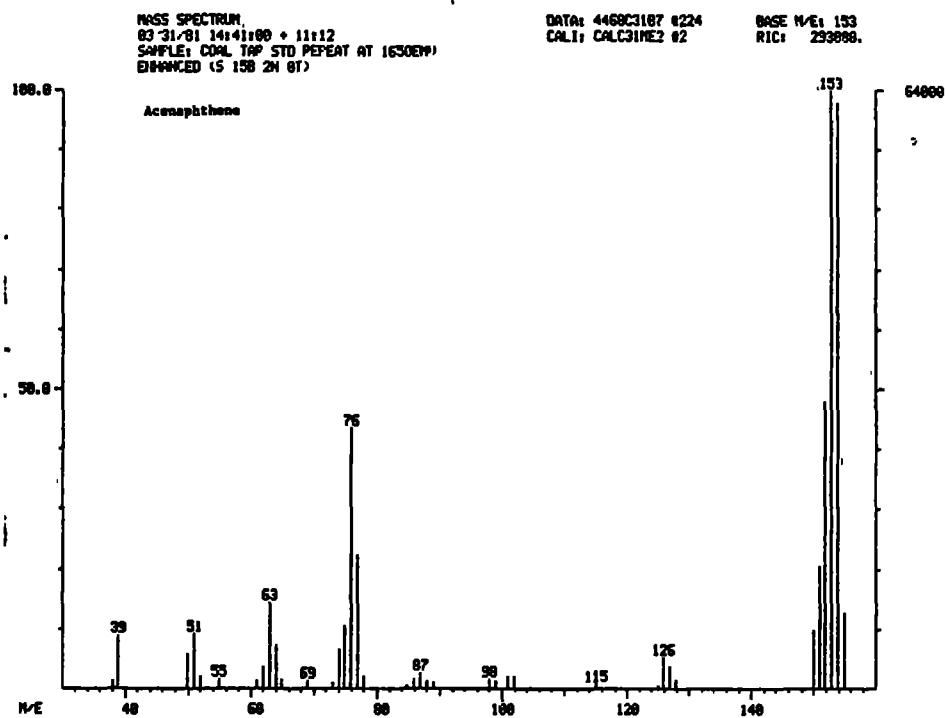


Figure 3. Mass spectrum of acenaphthene in standard.

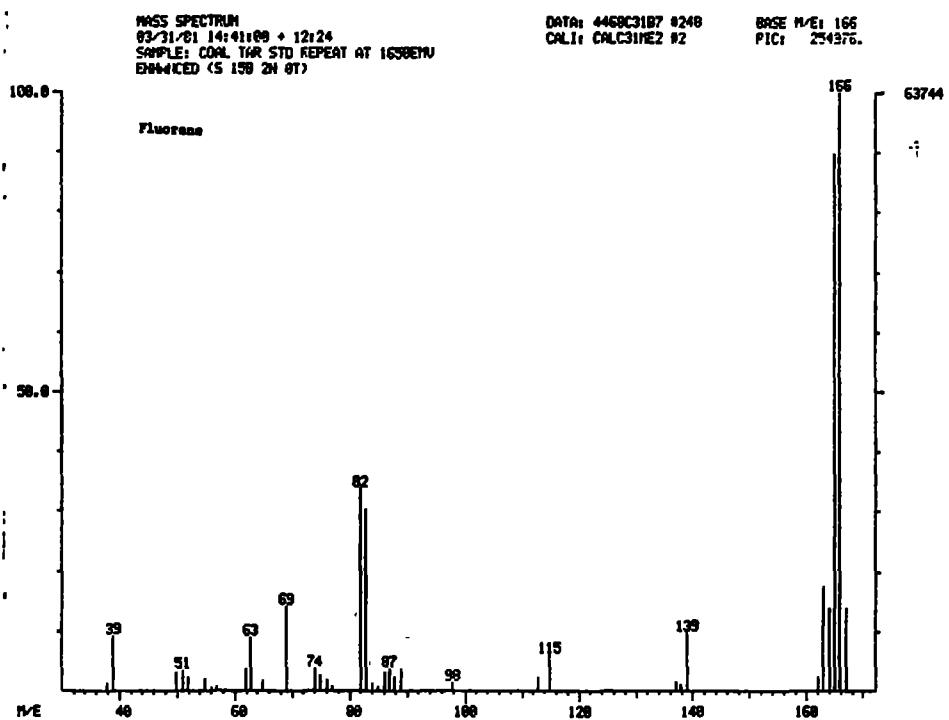


Figure 4. Mass spectrum of fluorene in standard.

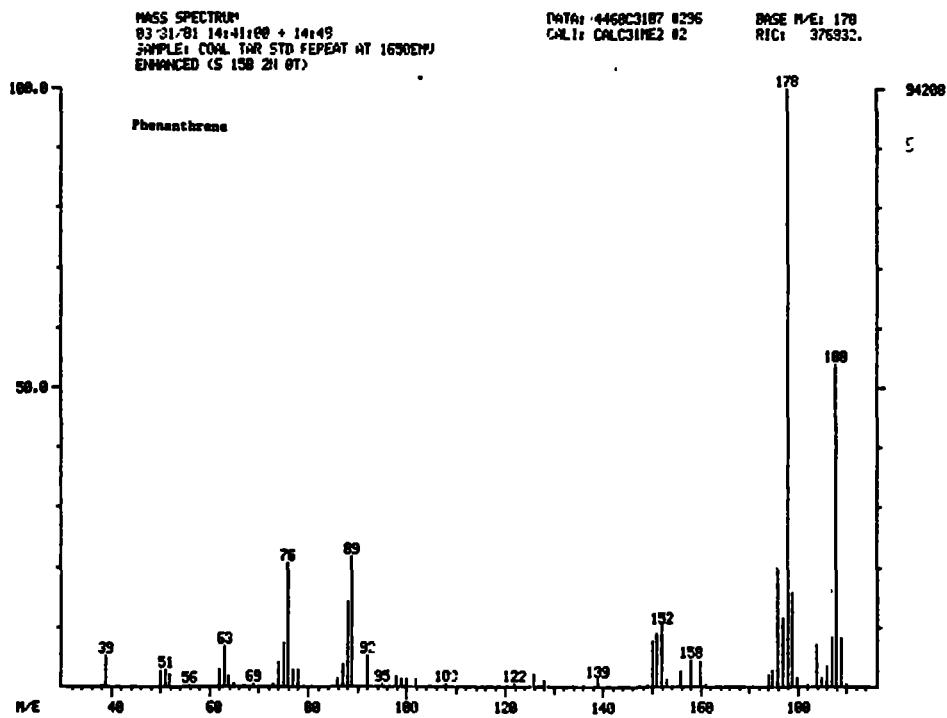


Figure 5. Mass spectrum of phenanthrene in standard.

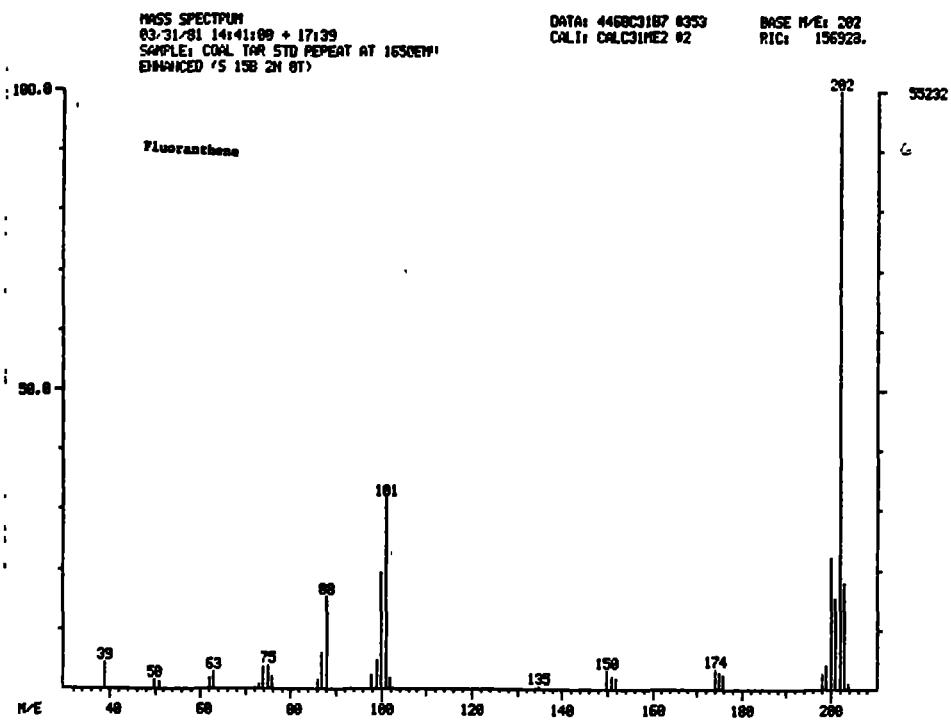


Figure 6. Mass spectrum of fluoranthene in standard.

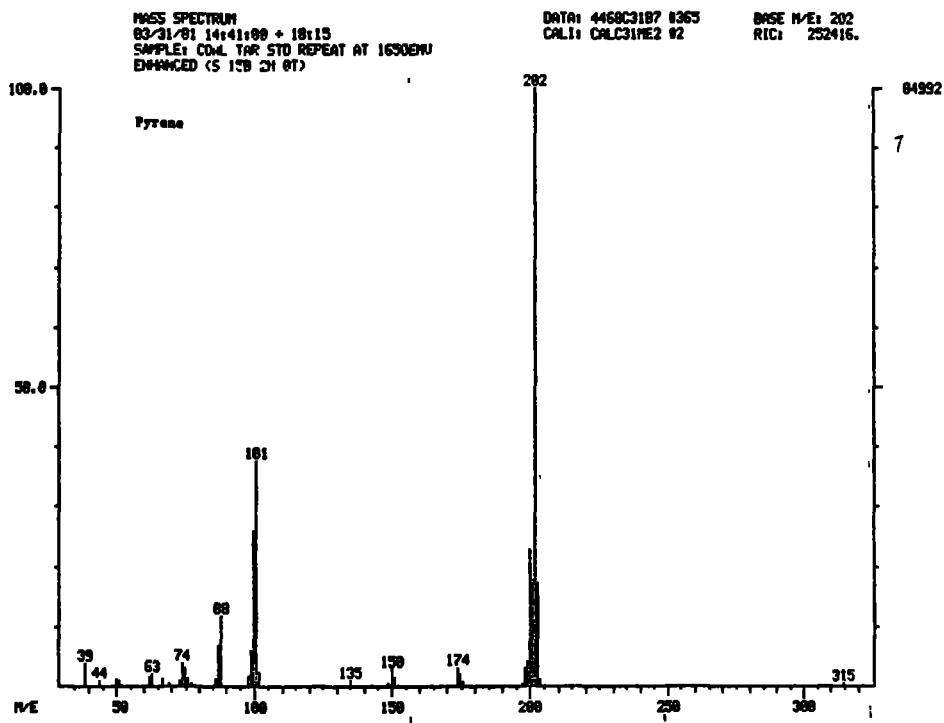


Figure 7. Mass spectrum of pyrene in standard.

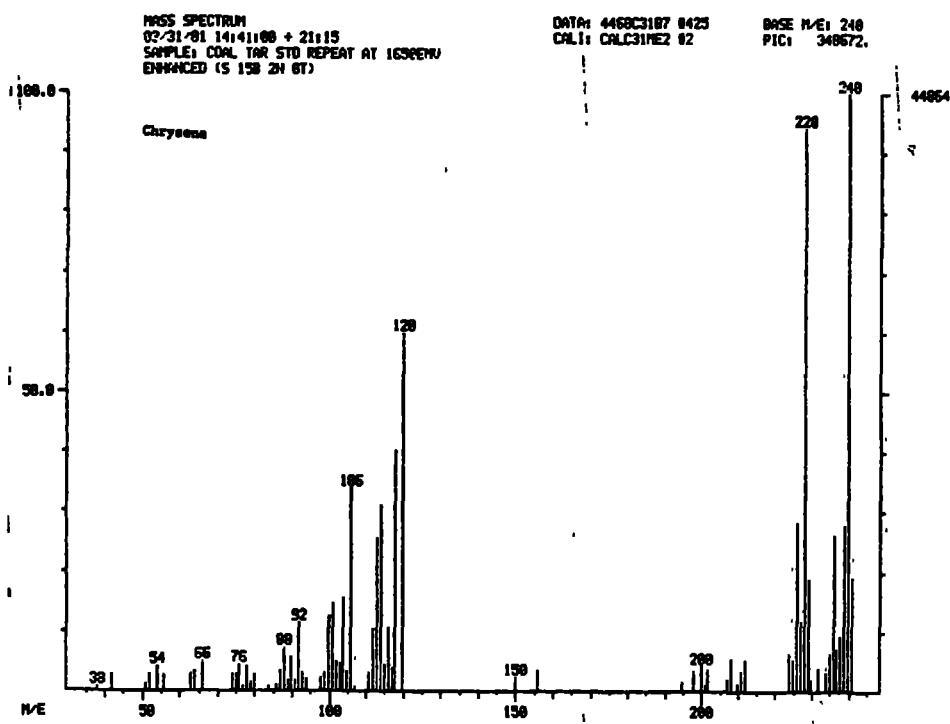


Figure 8. Mass spectrum of chrysene in standard.

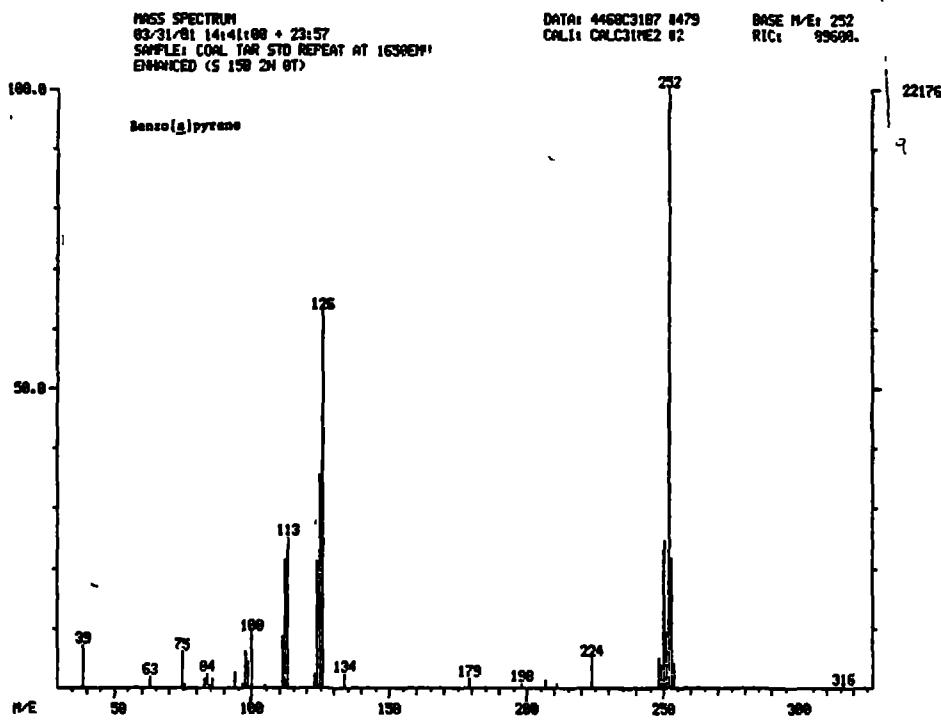


Figure 9. Mass spectrum of benzo[a]pyrene in standard.

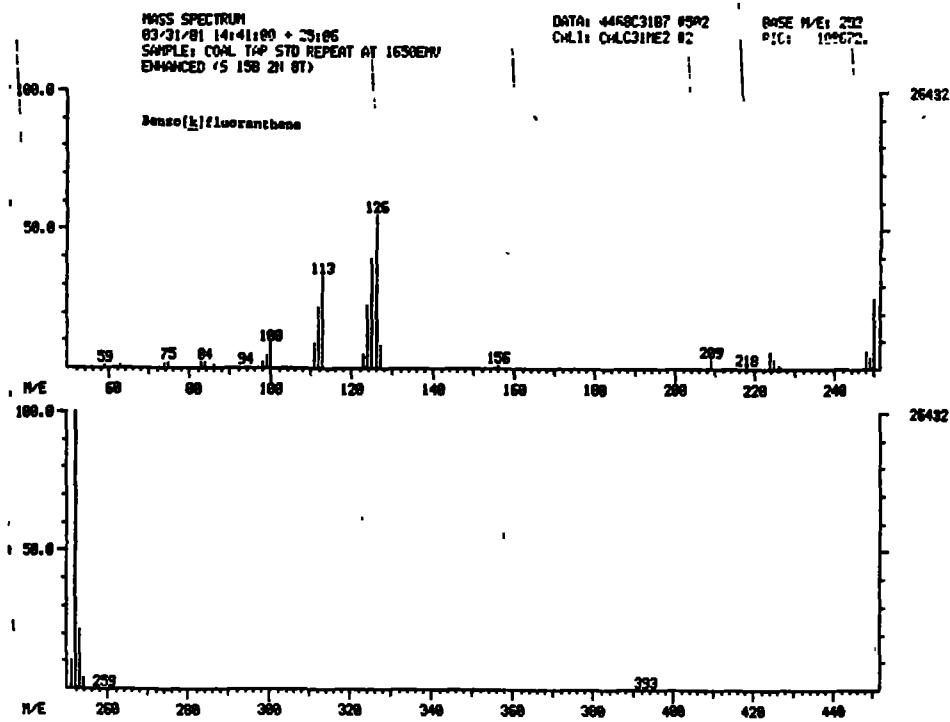


Figure 10. Mass spectrum of benzo[k]fluoranthene in standard.

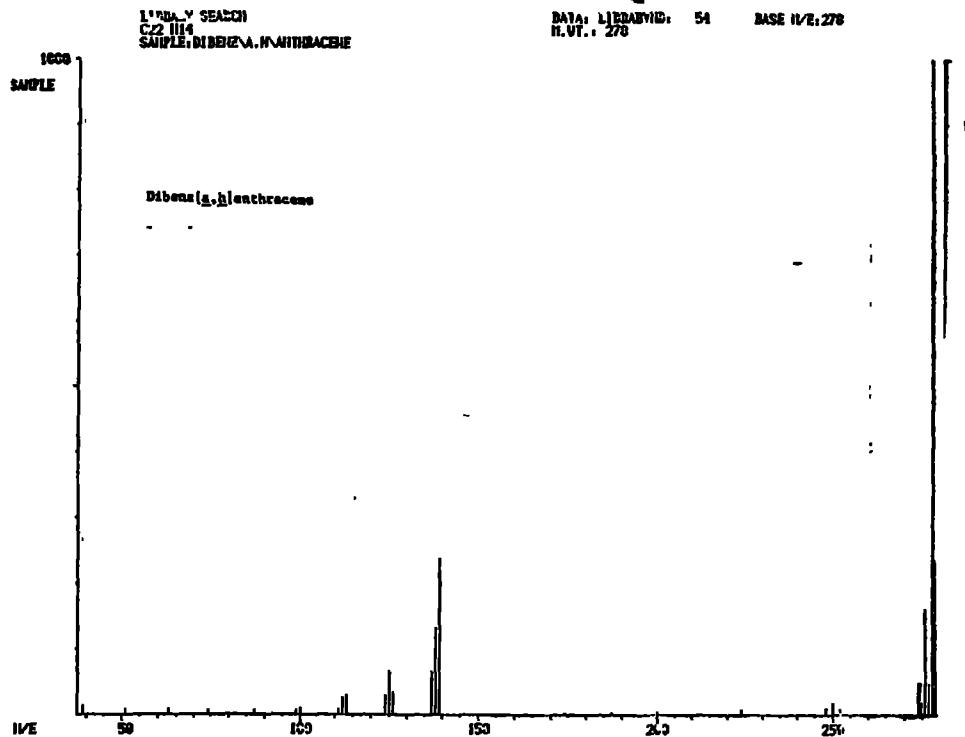


Figure 11. Mass spectrum of dibenz[a,h]anthracene from computer library.

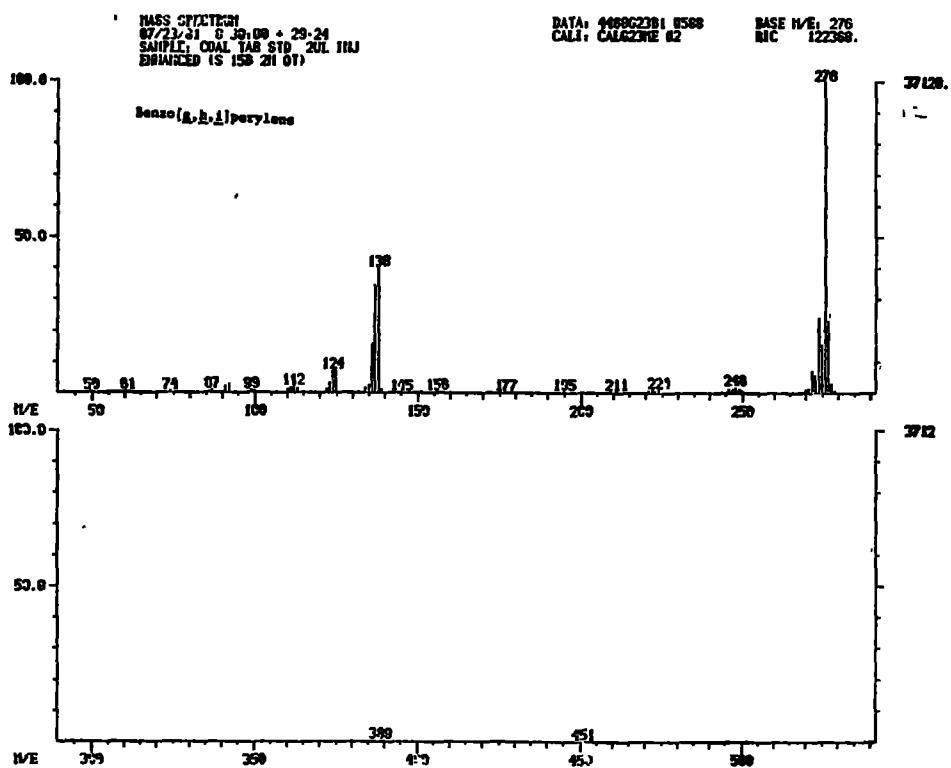


Figure 12. Mass spectrum of benzo[g,h,i]perylene in standard.

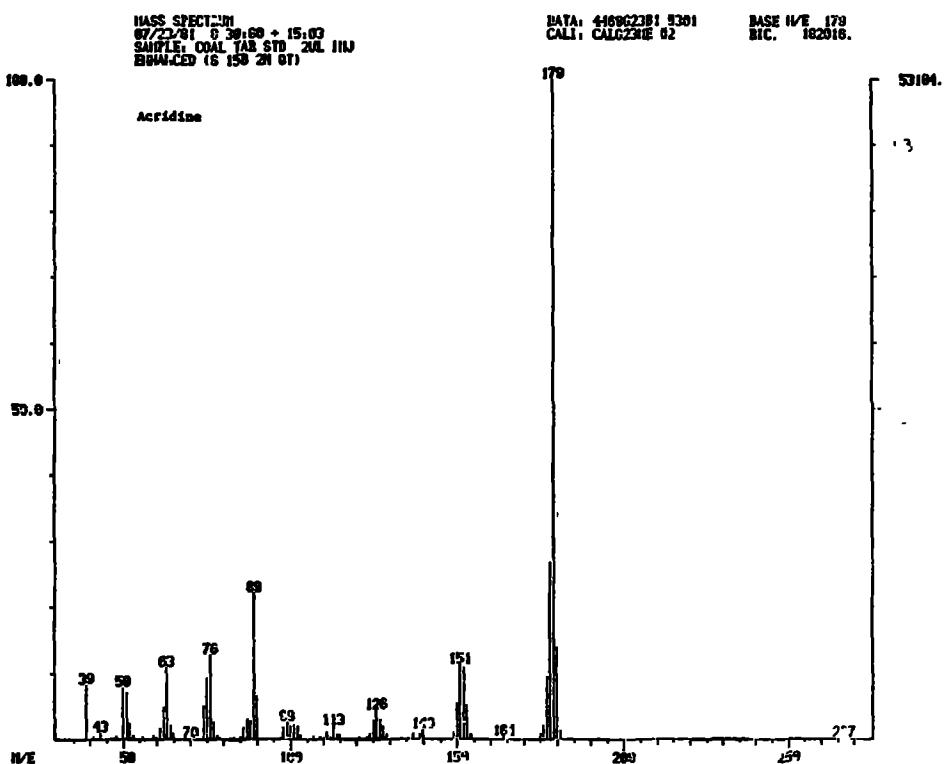


Figure 13. Mass spectrum of acridine in standard.

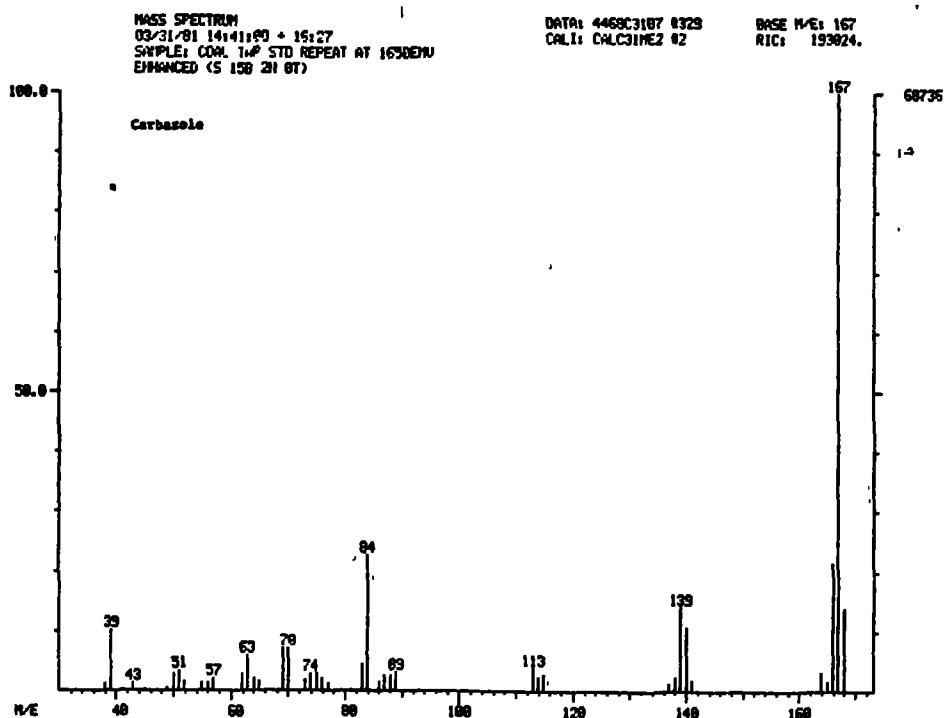


Figure 14. Mass spectrum of carbazole in standard.

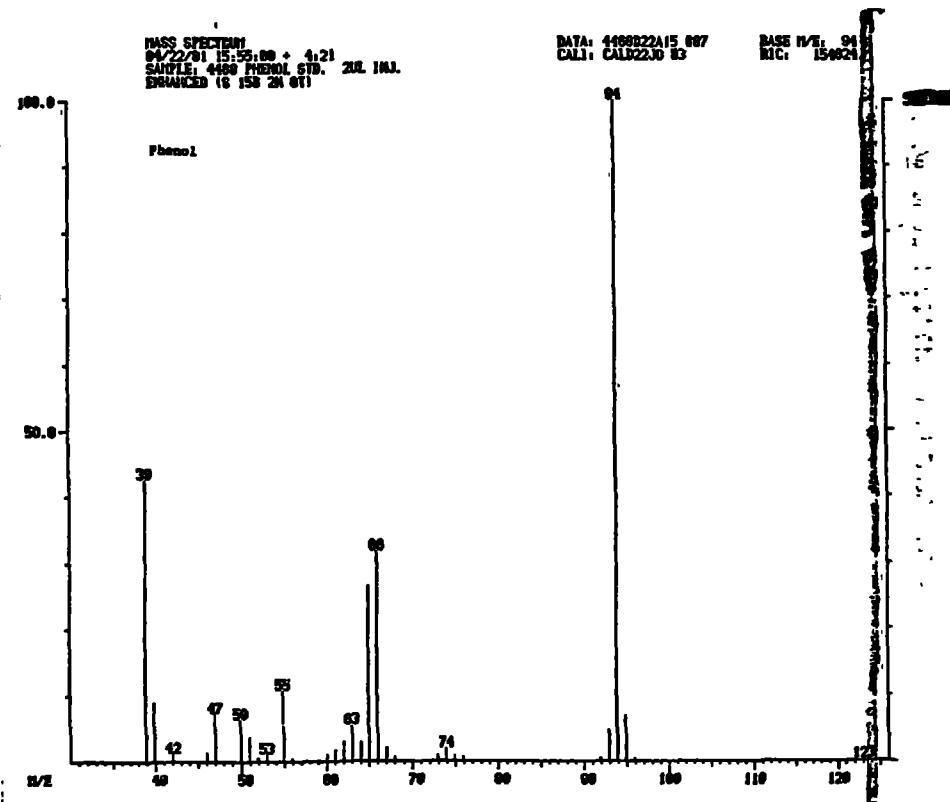


Figure 15. Mass spectrum of phenol in standard.

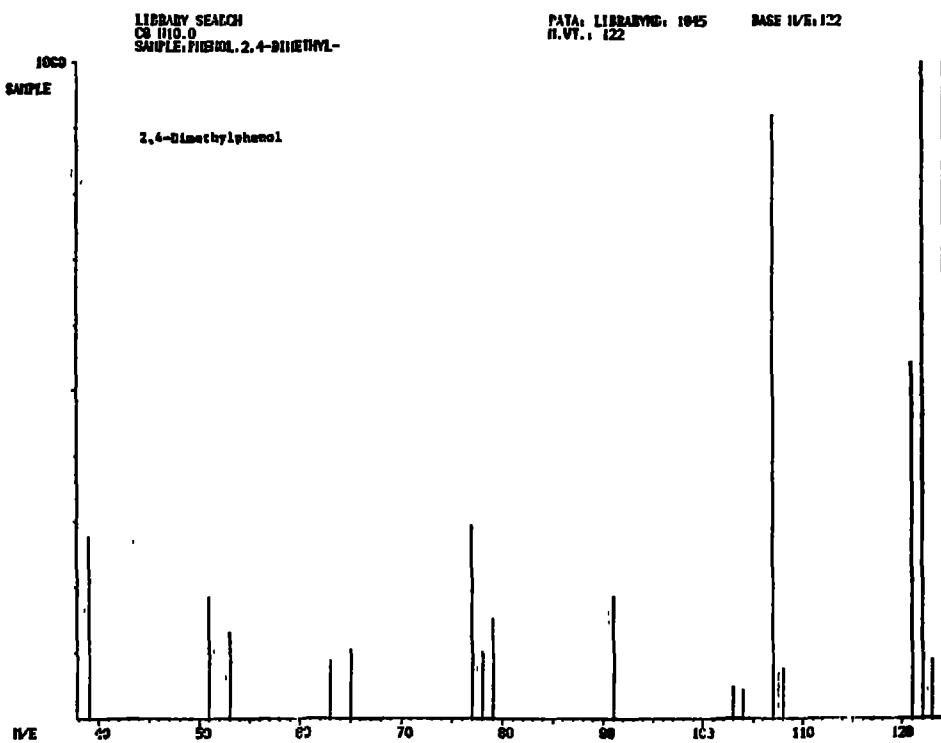


Figure 16. Mass spectrum of 2,4-dimethylphenol in standard.

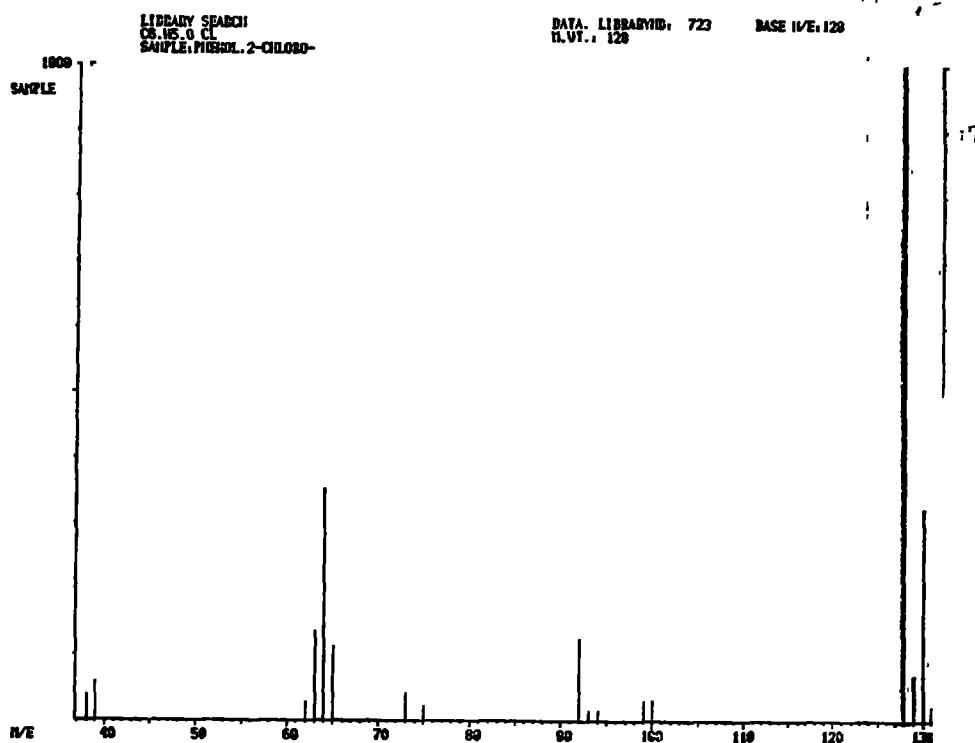


Figure 17. Mass spectrum of 2-chlorophenol from computer library.

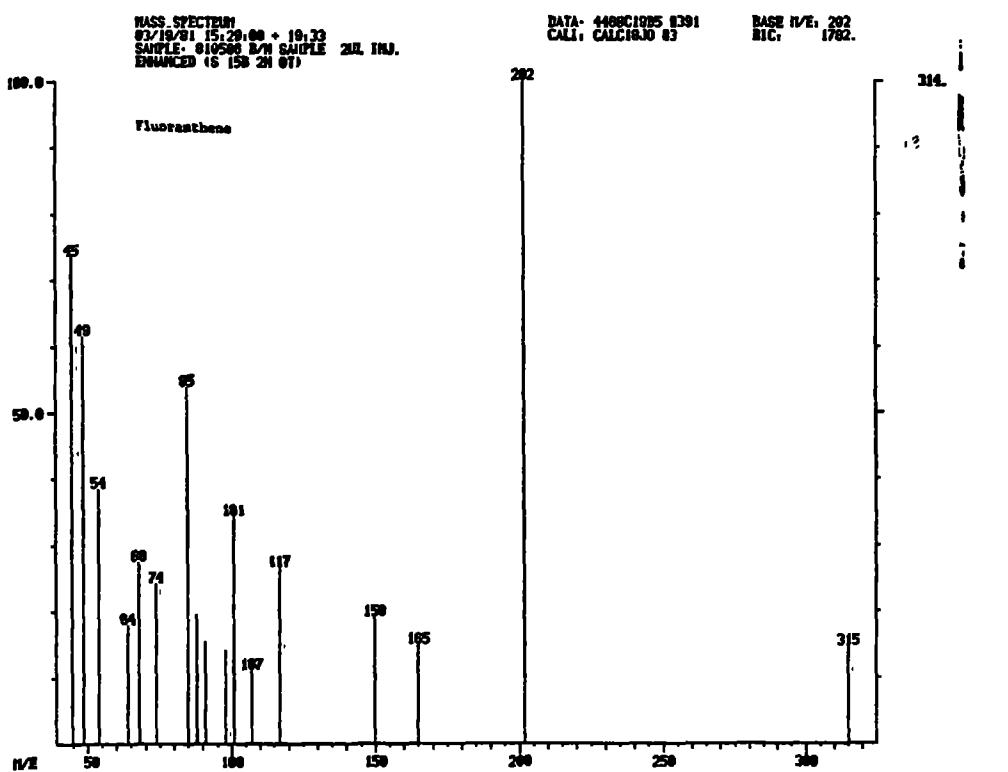


Figure 18. Mass spectrum of fluoranthene in sample 810506.

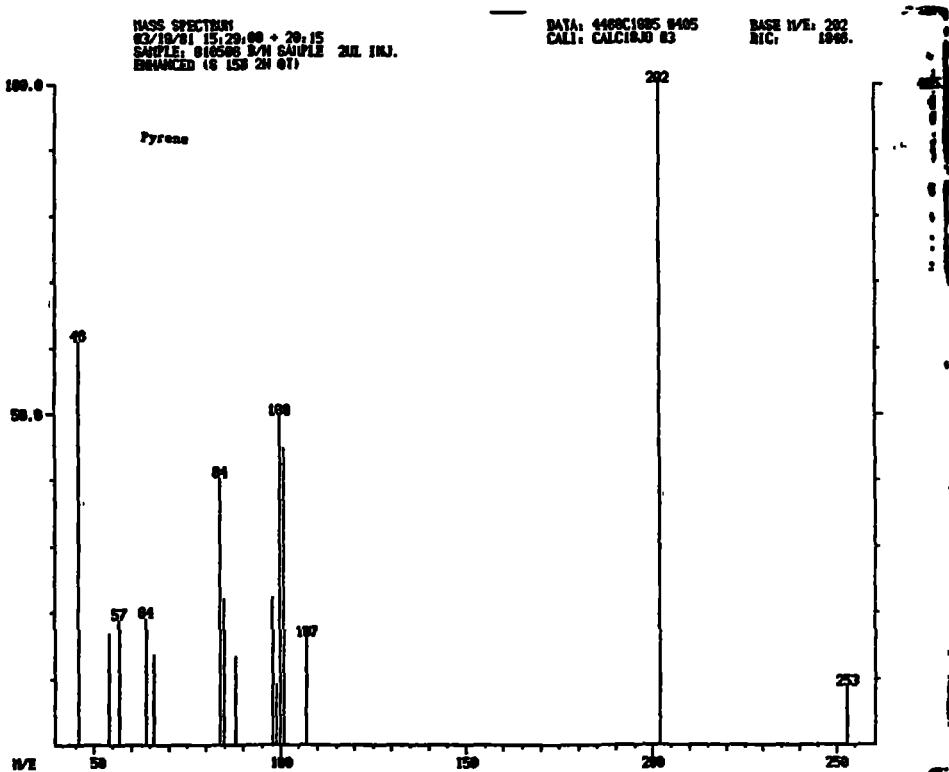


Figure 19. Mass spectrum of pyrene in sample 810506.

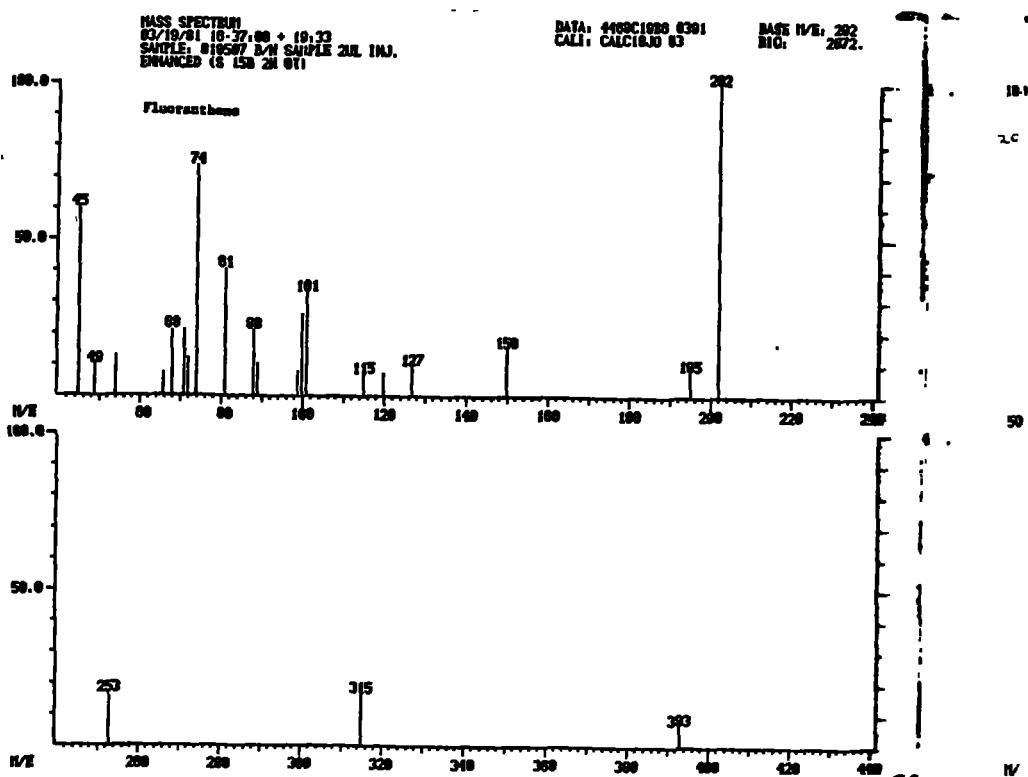


Figure 20. Mass spectrum of fluoranthene in sample 810507.

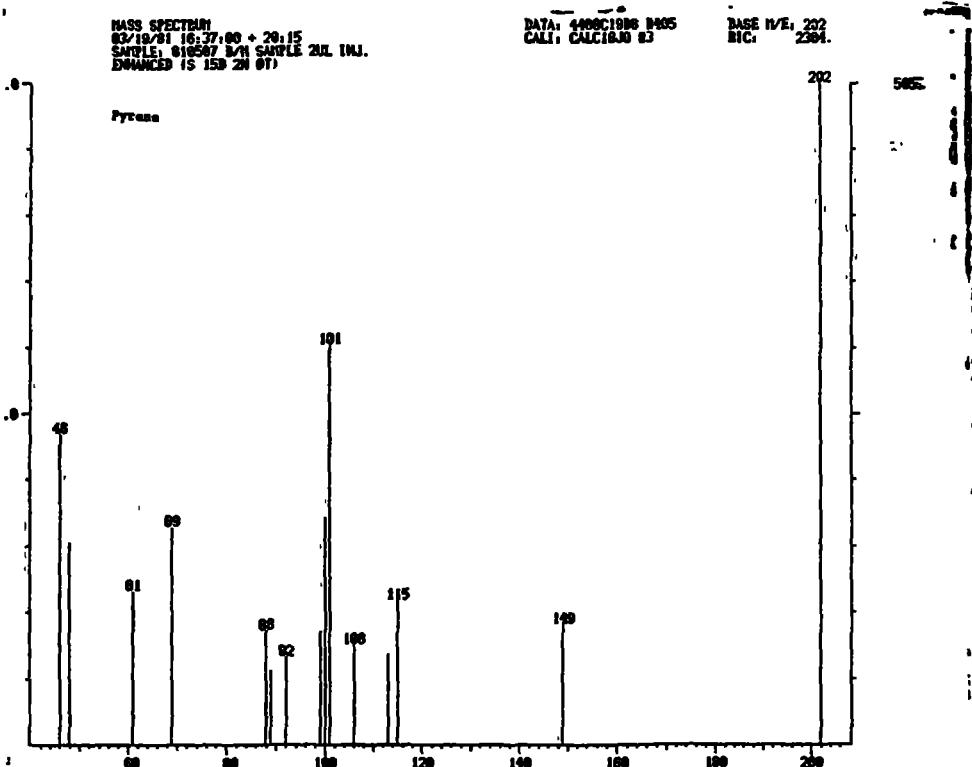


Figure 21. Mass spectrum of pyrene in sample 810507.

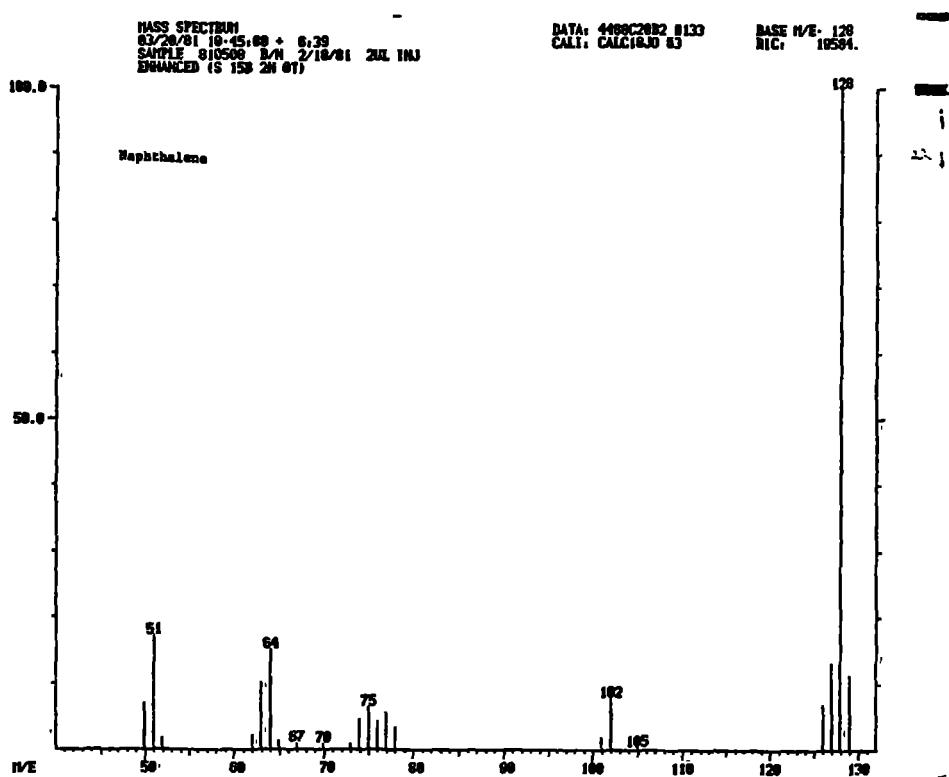


Figure 22. Mass spectrum of naphthalene in sample 810508.

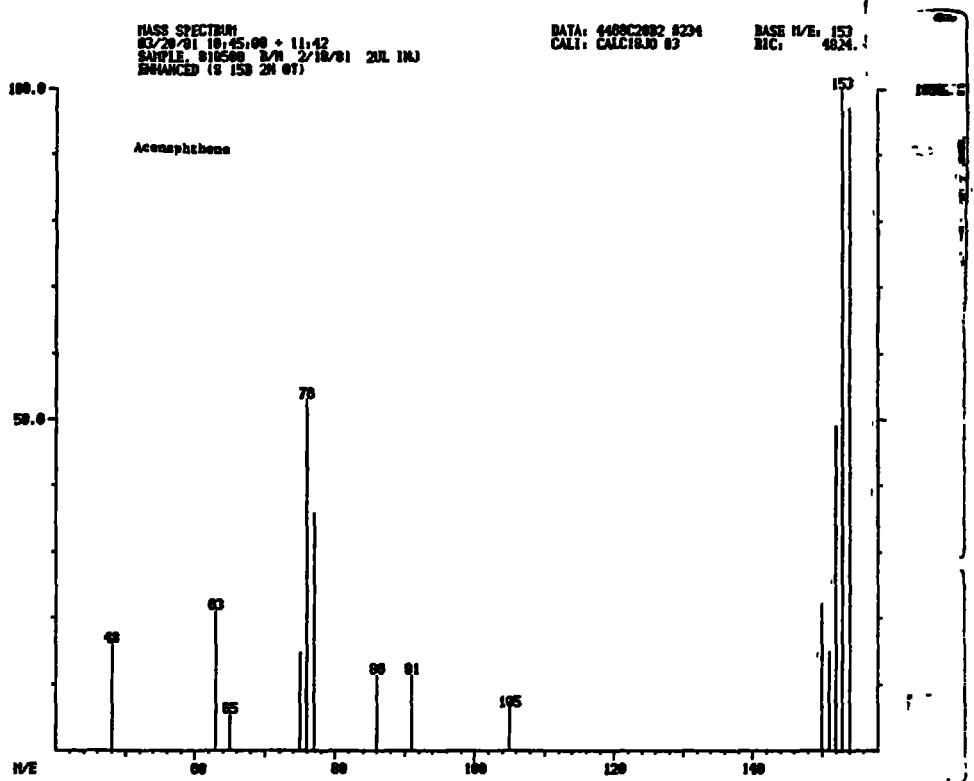


Figure 23. Mass spectrum of acenaphthene in sample 810508.

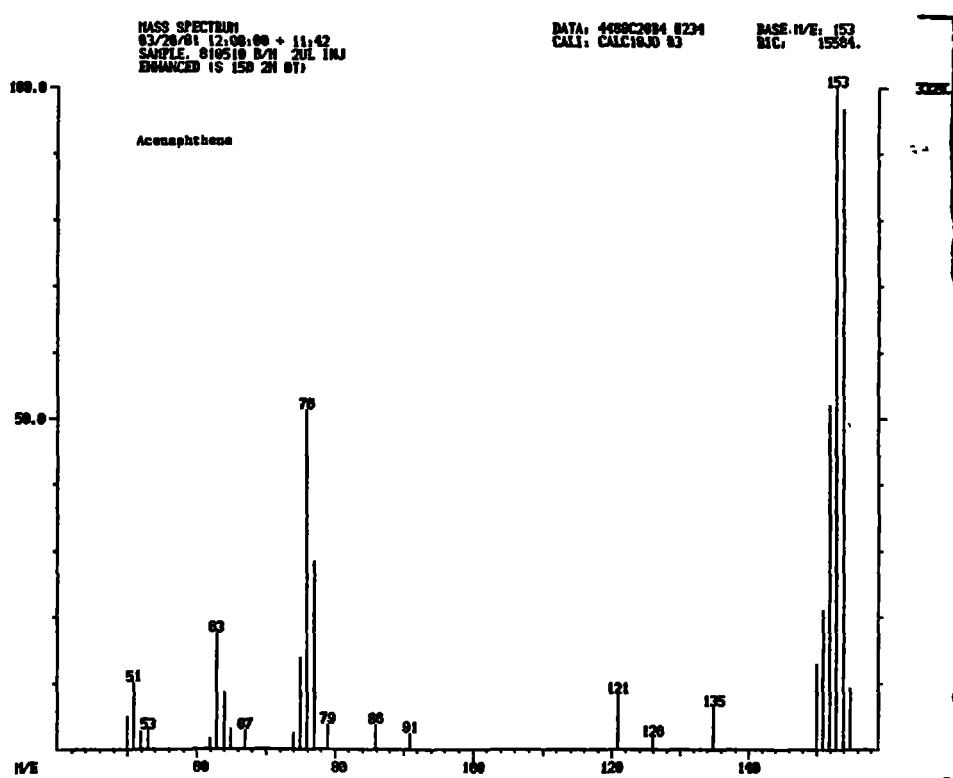


Figure 24. Mass spectrum of acenaphthene in sample 810510.

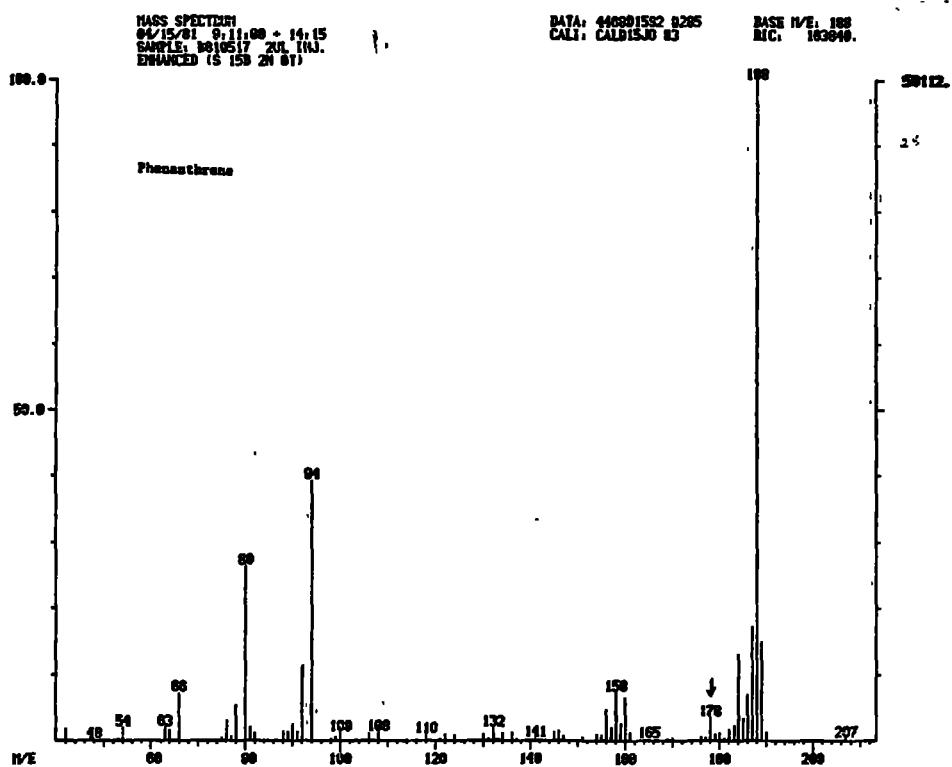


Figure 25. Mass spectrum of phenanthrene in sample 810517.

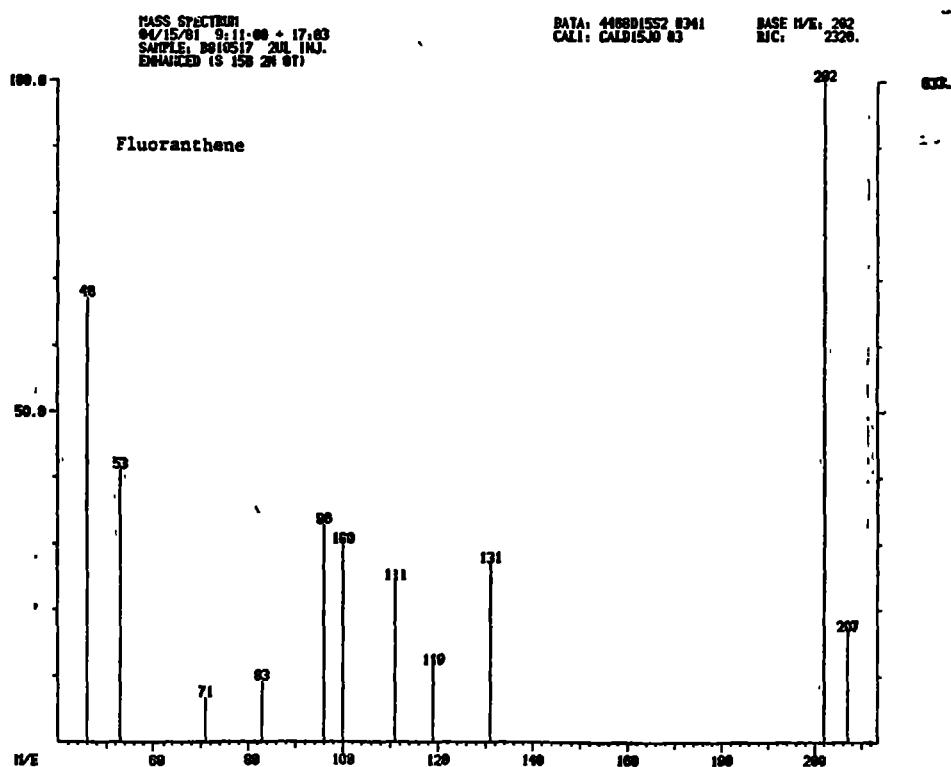


Figure 26. Mass spectrum of fluoranthene in sample 810517.

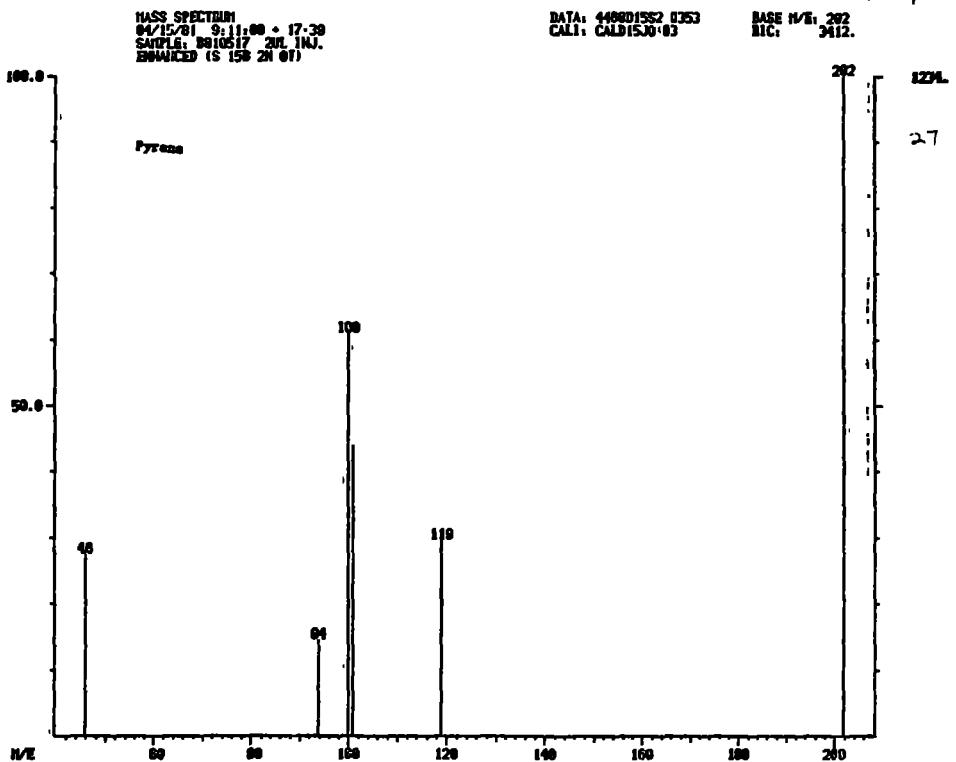


Figure 27. Mass spectrum of pyrene in sample 810517.

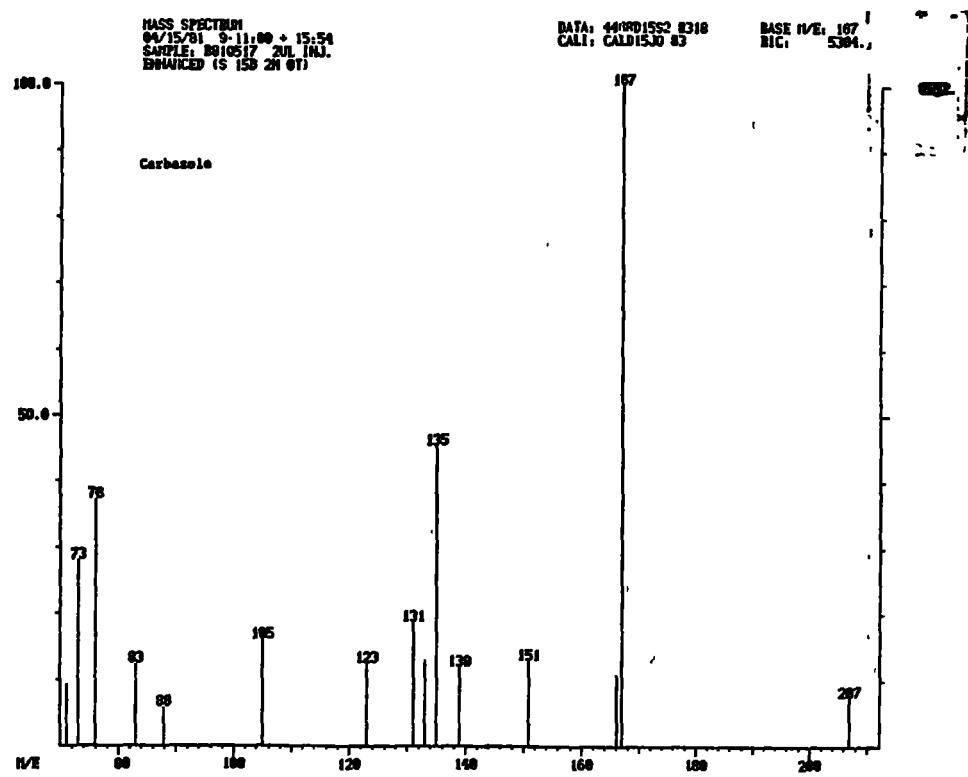


Figure 28. Mass spectrum of carbazole in sample 810517.

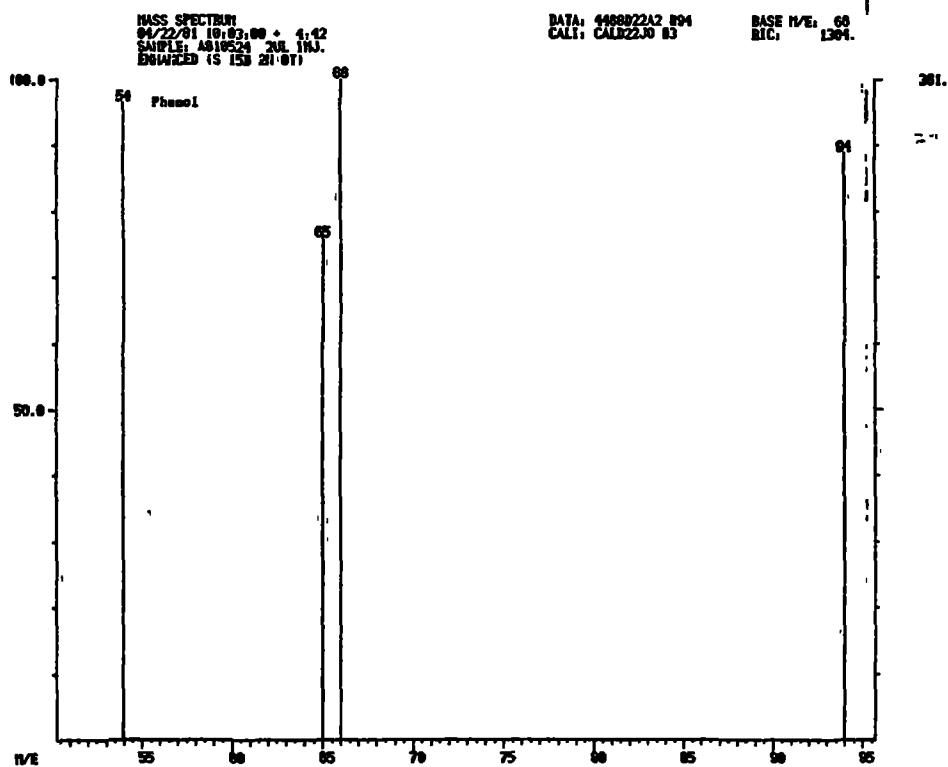


Figure 29. Mass spectrum of phenol in sample 810524.

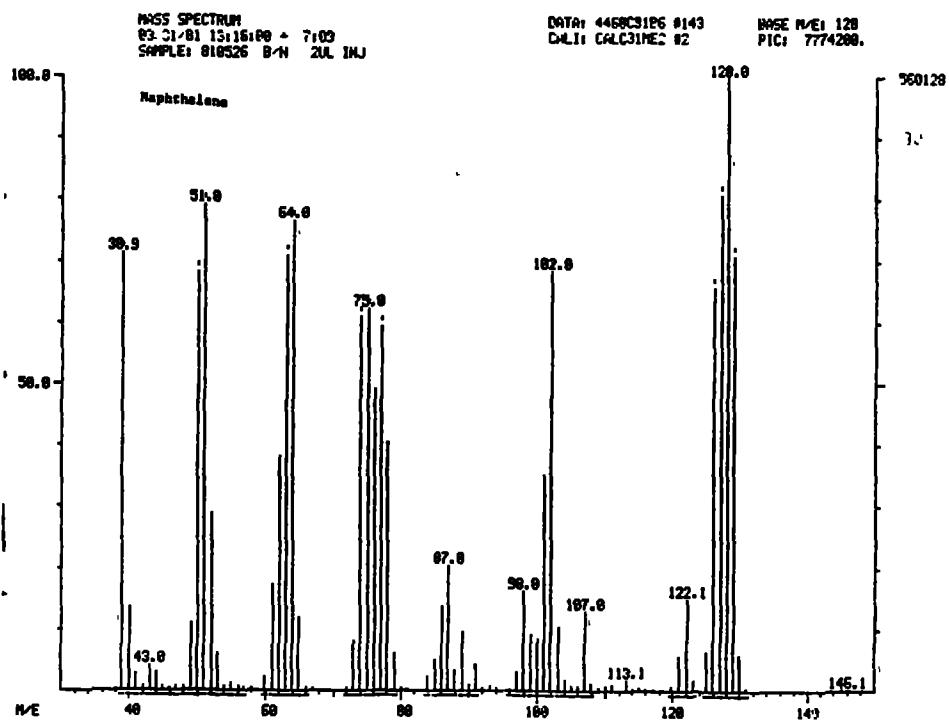


Figure 30. Mass spectrum of naphthalene in sample 810526.

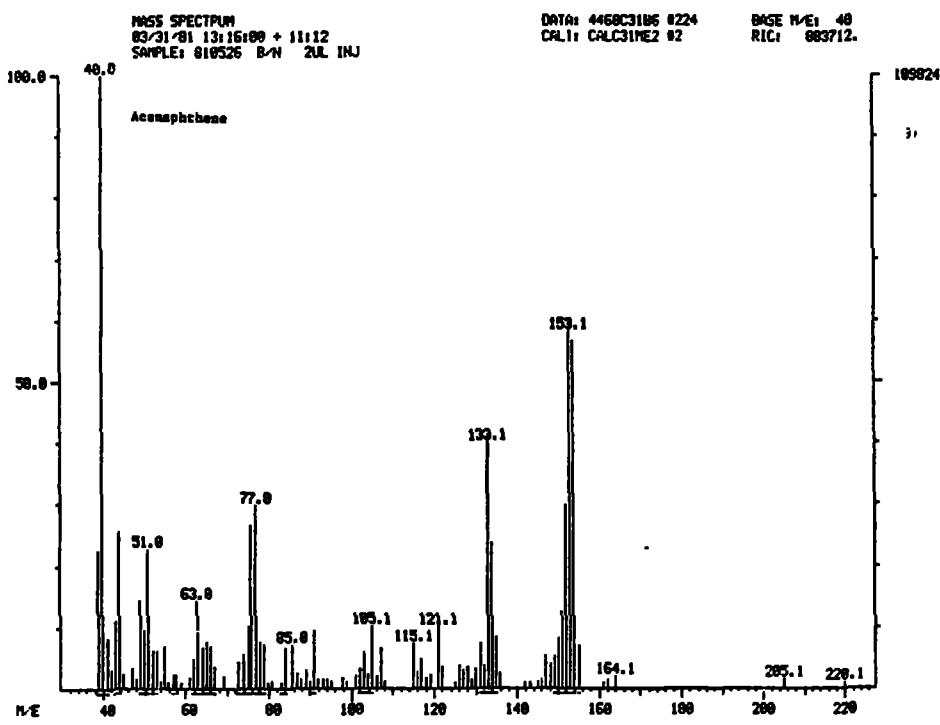


Figure 31. Mass spectrum of acenaphthene in sample 810526.

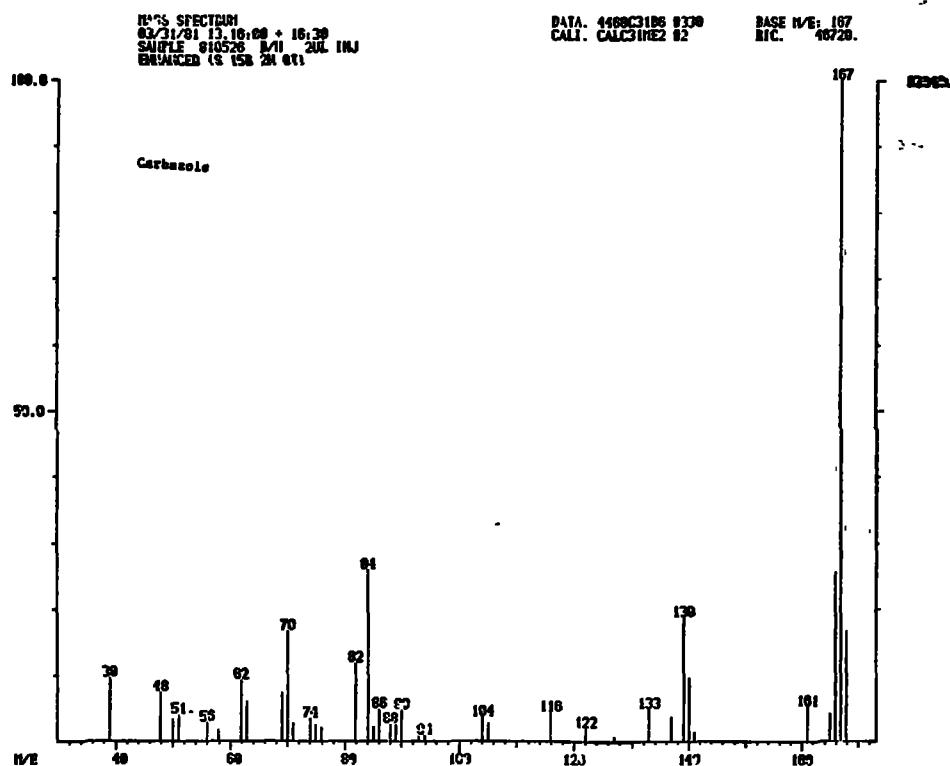


Figure 32. Mass spectrum of carbazole in sample 810526.

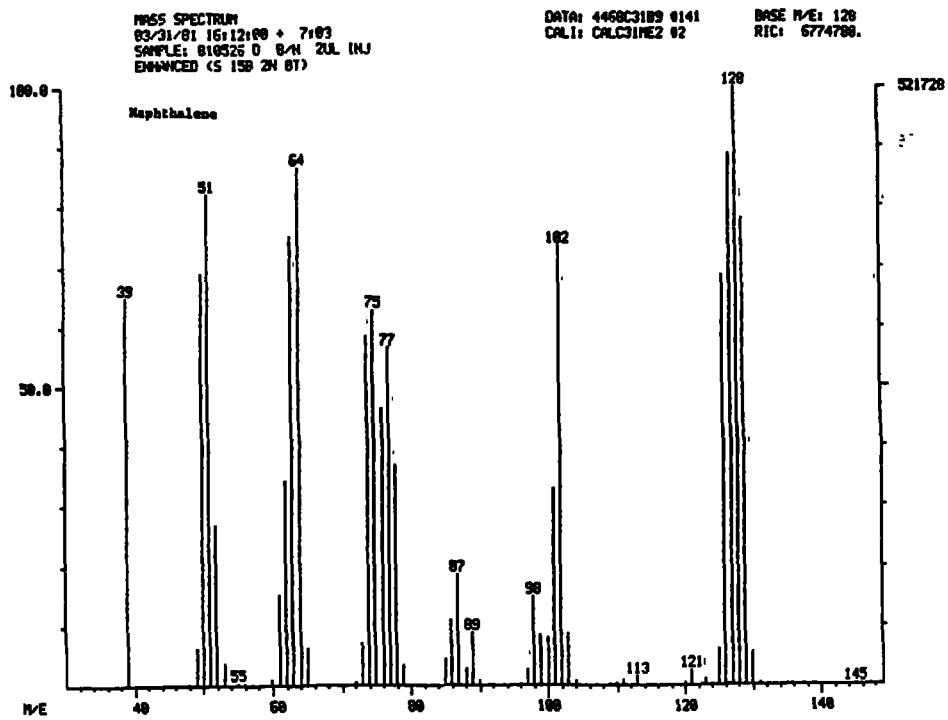


Figure 33. Mass spectrum of naphthalene in sample 810526D.

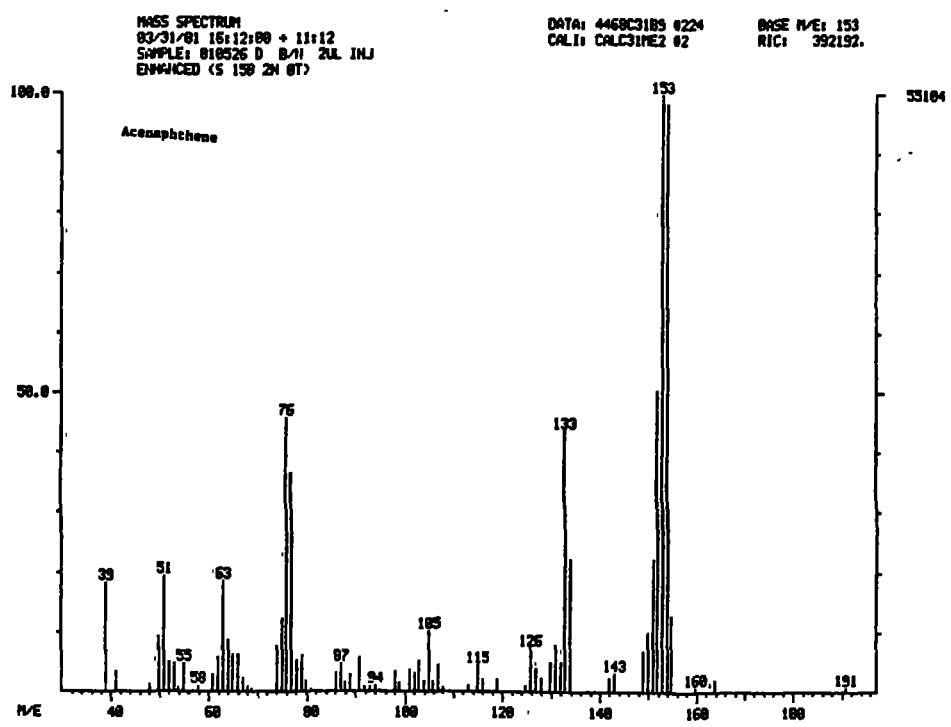


Figure 34. Mass spectrum of acenaphthene in sample 810526D.

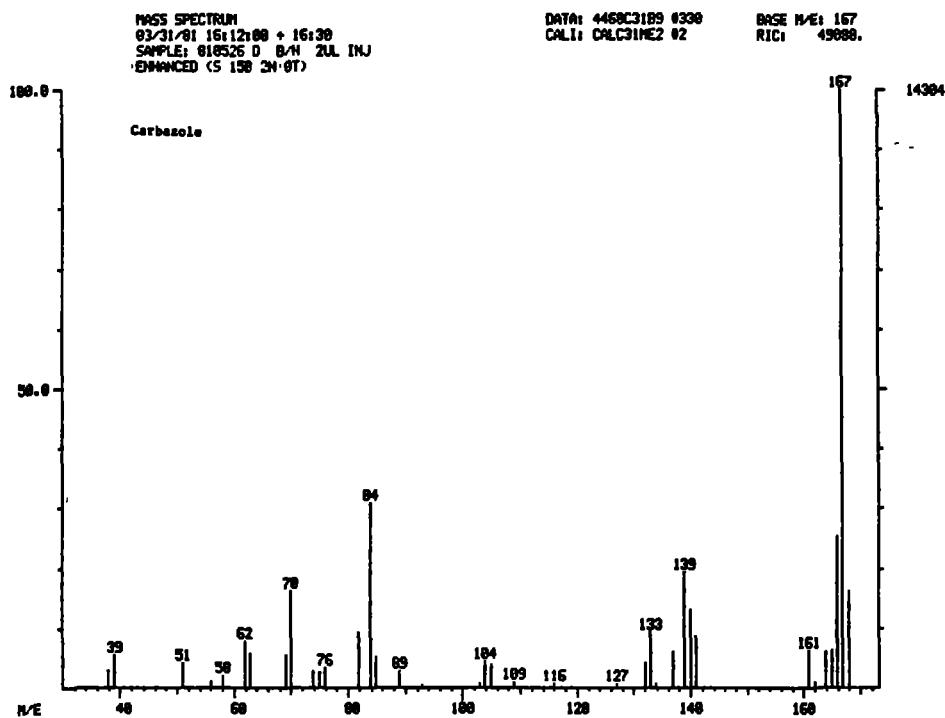


Figure 35. Mass spectrum f carbazole in sample 810526D.

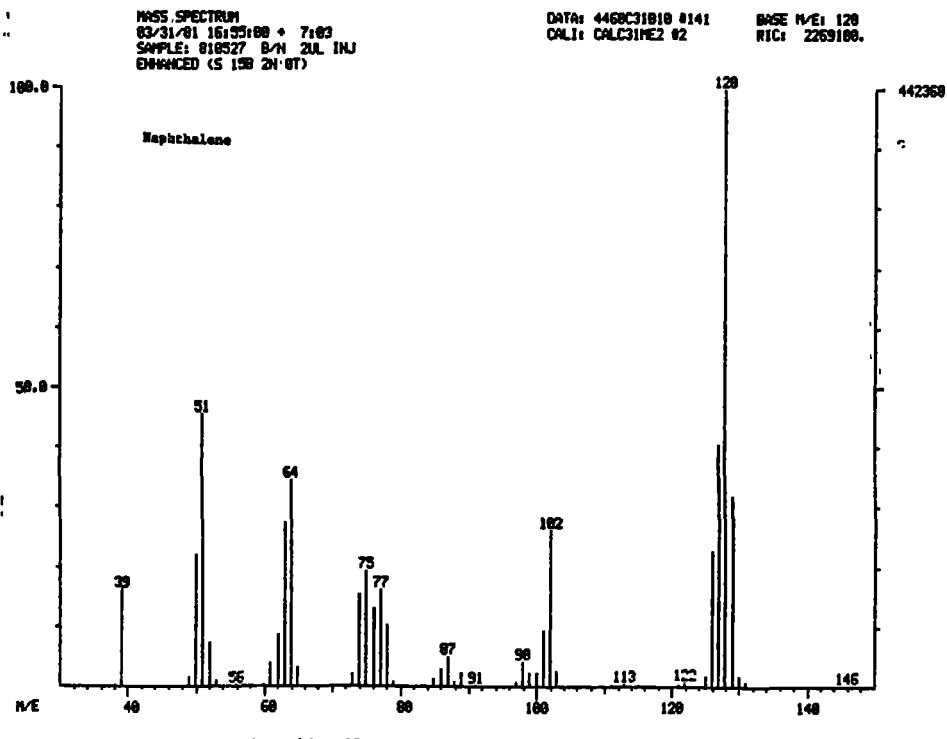


Figure 36. Mass spectrum of naphthalene in sample 810527.

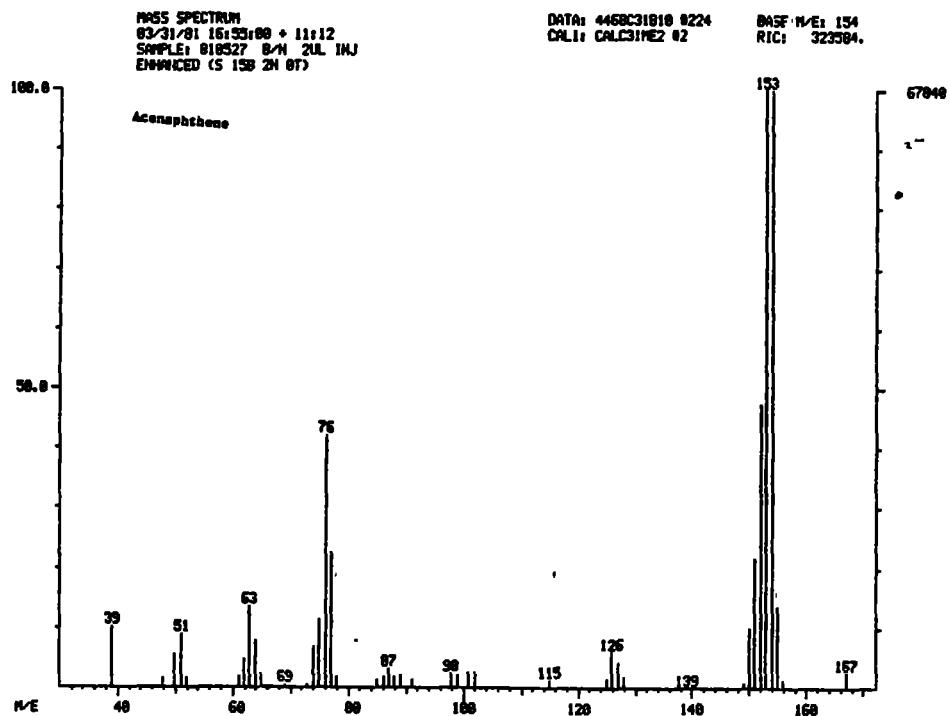


Figure 37. Mass spectrum of acenaphthene in sample 810527.

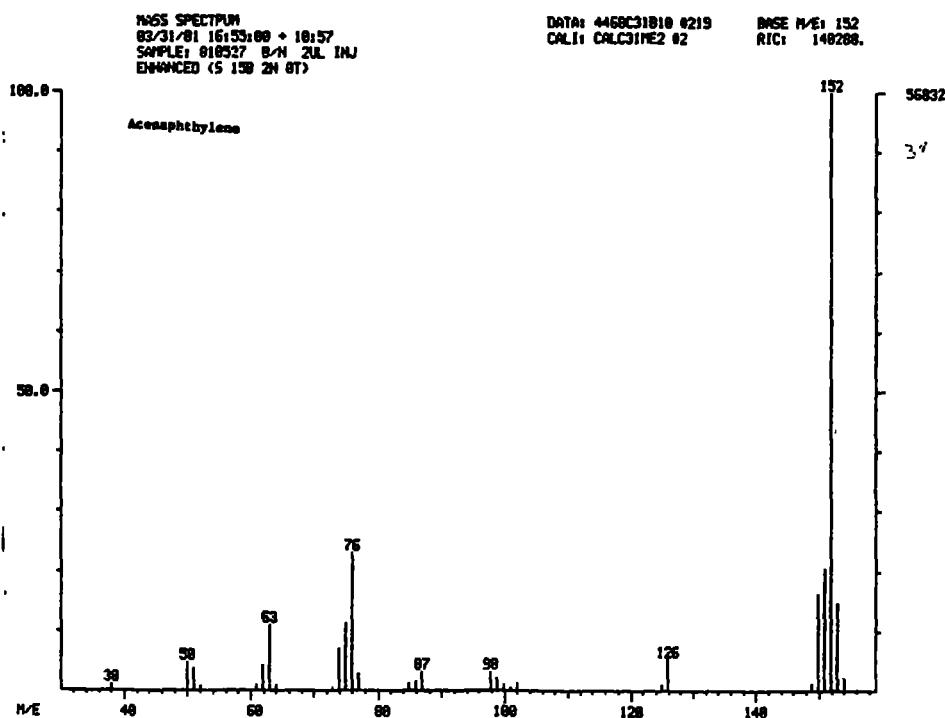


Figure 38.. Mass spectrum of acenaphthylene in sample 810527.

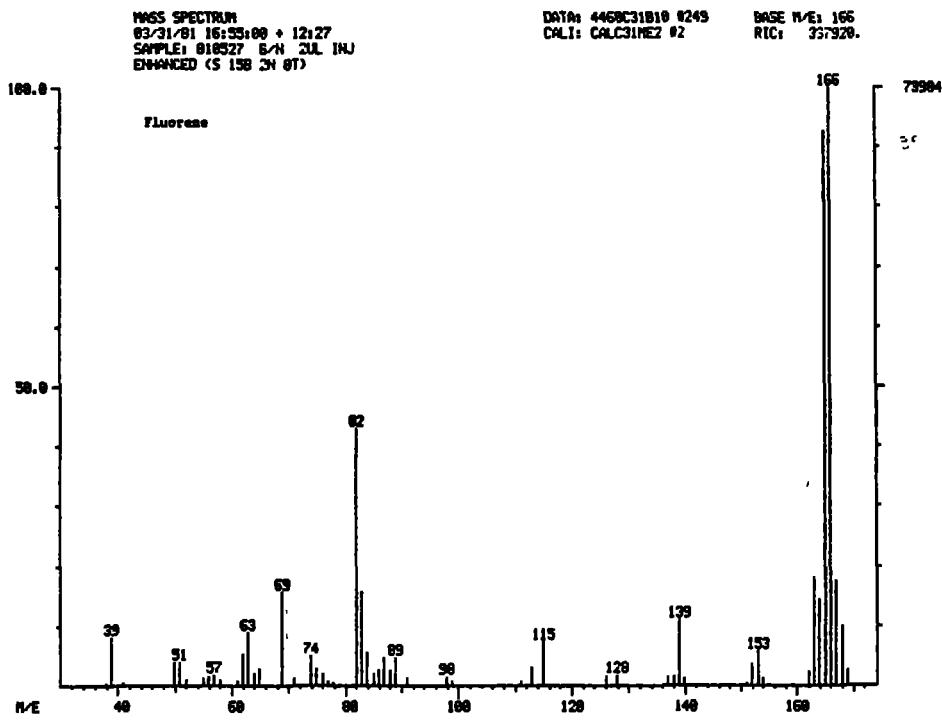


Figure 39. Mass spectrum of fluorene in sample 810527.

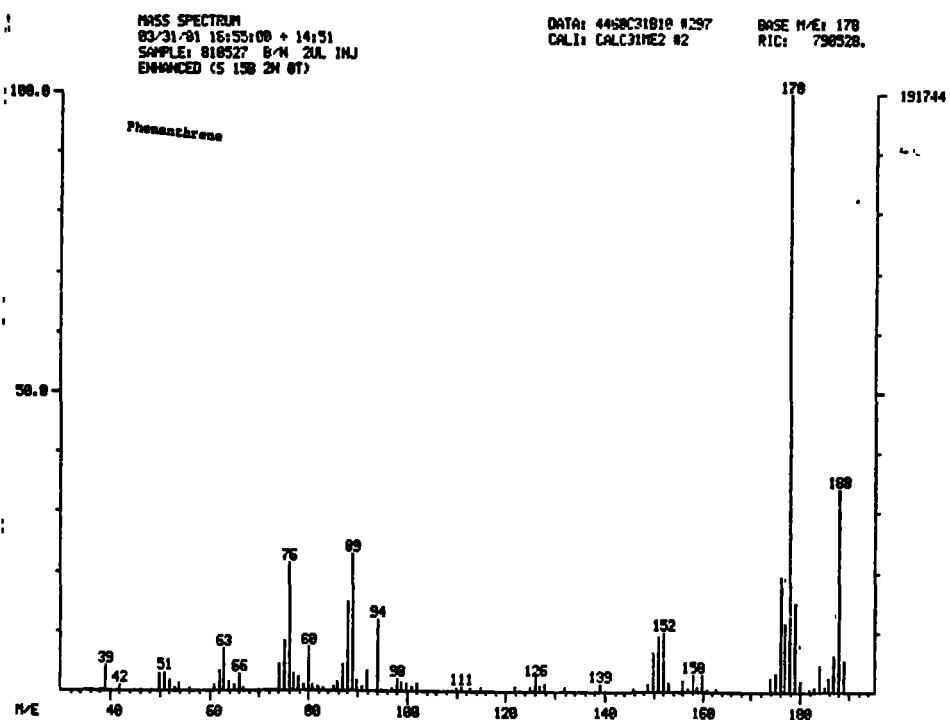


Figure 40. Mass spectrum of phenanthrene in sample 810527.

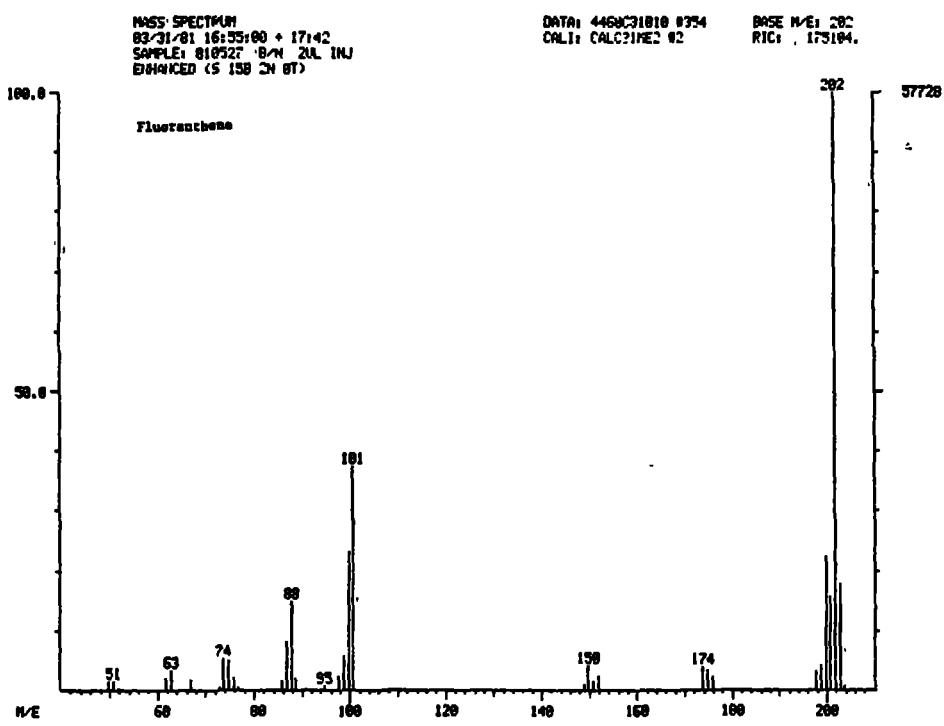


Figure 41. Mass spectrum of fluoranthene in sample 810527.

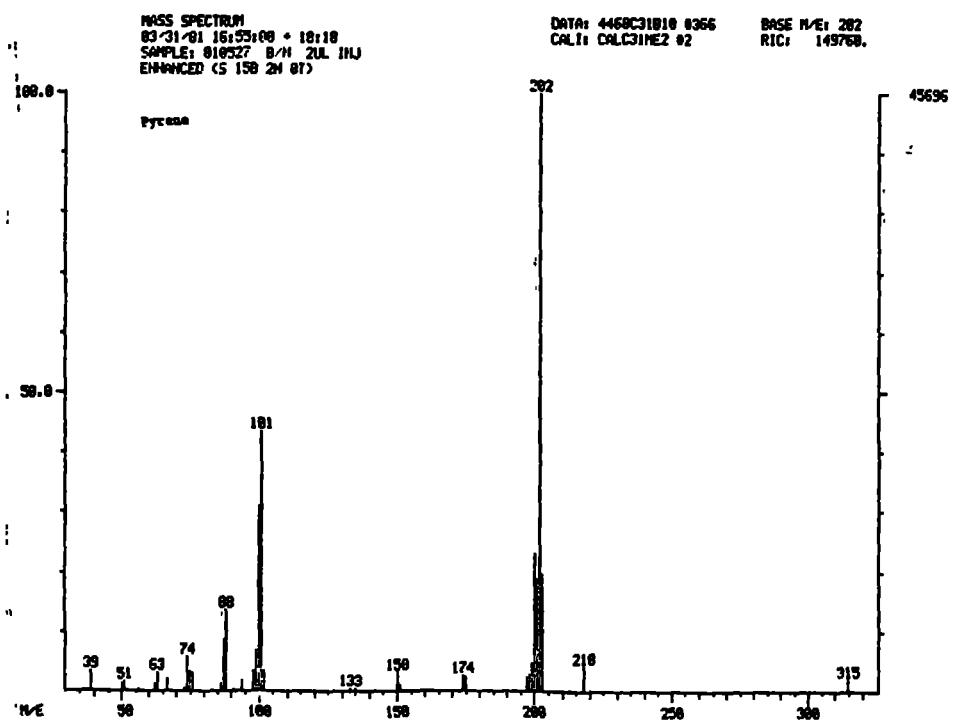


Figure 42. Mass spectrum of pyrene in sample 810527.

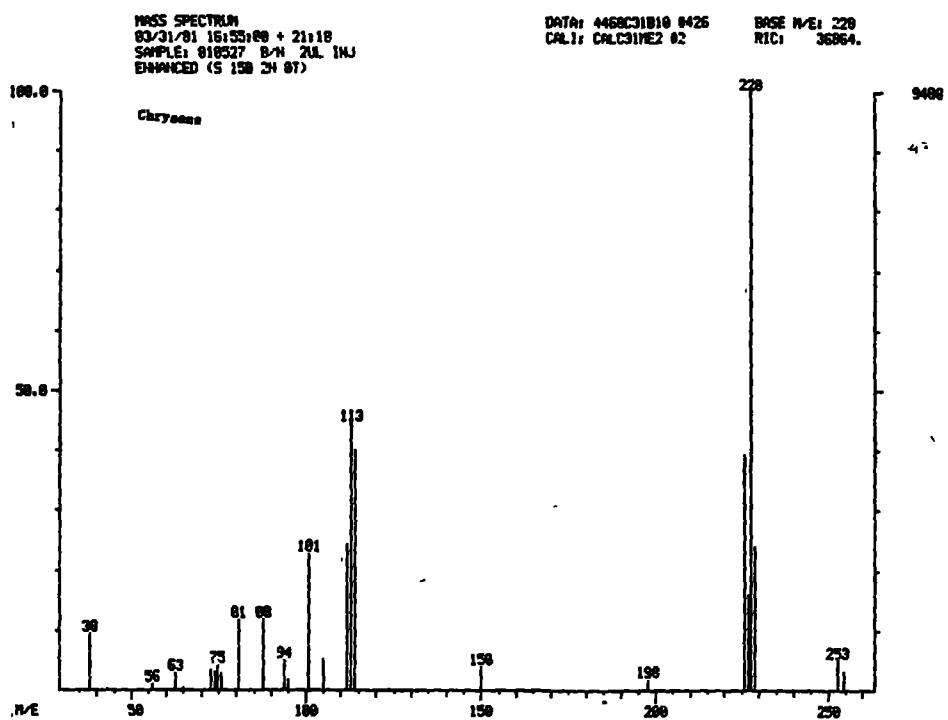


Figure 43. Mass spectrum of chrysene in sample 810527.

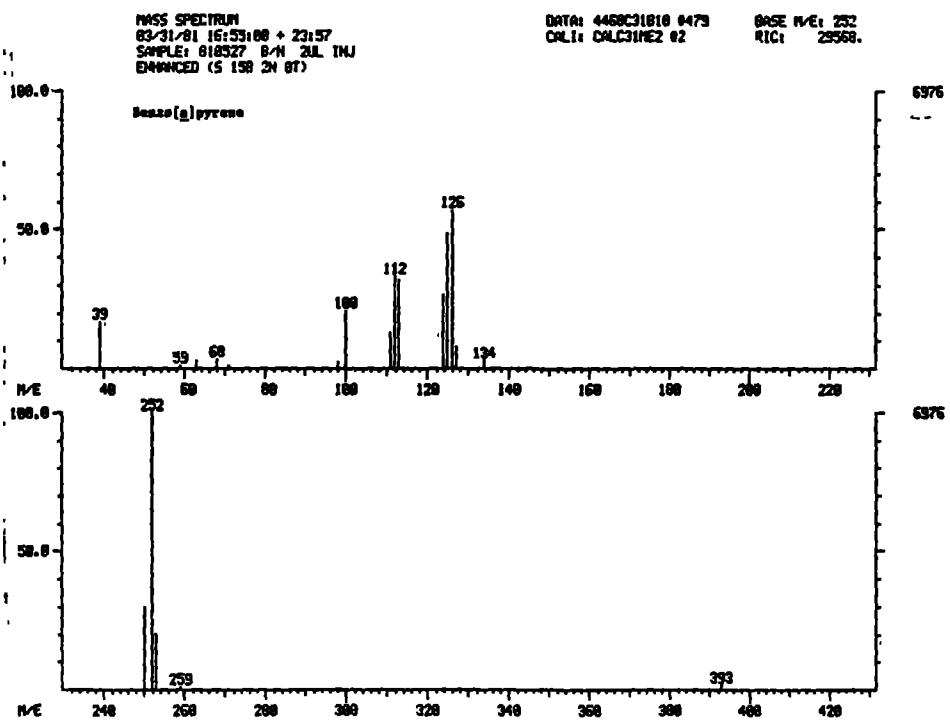


Figure 44. Mass spectrum of benzo[a]pyrene in sample 810527.

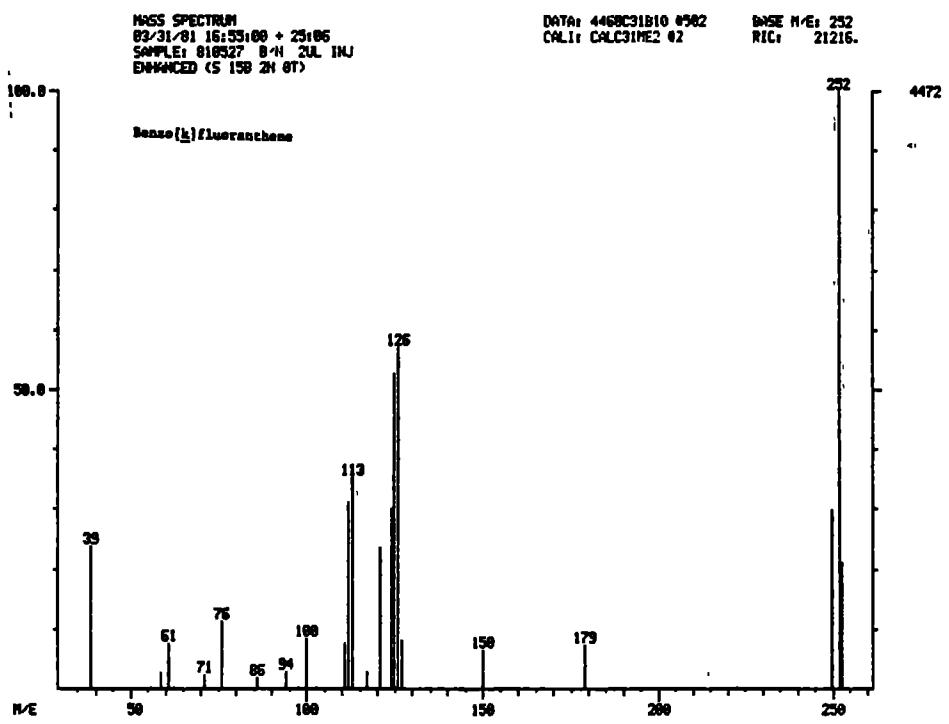


Figure 45. Mass spectrum of benzo[k]fluoranthene in 810527.

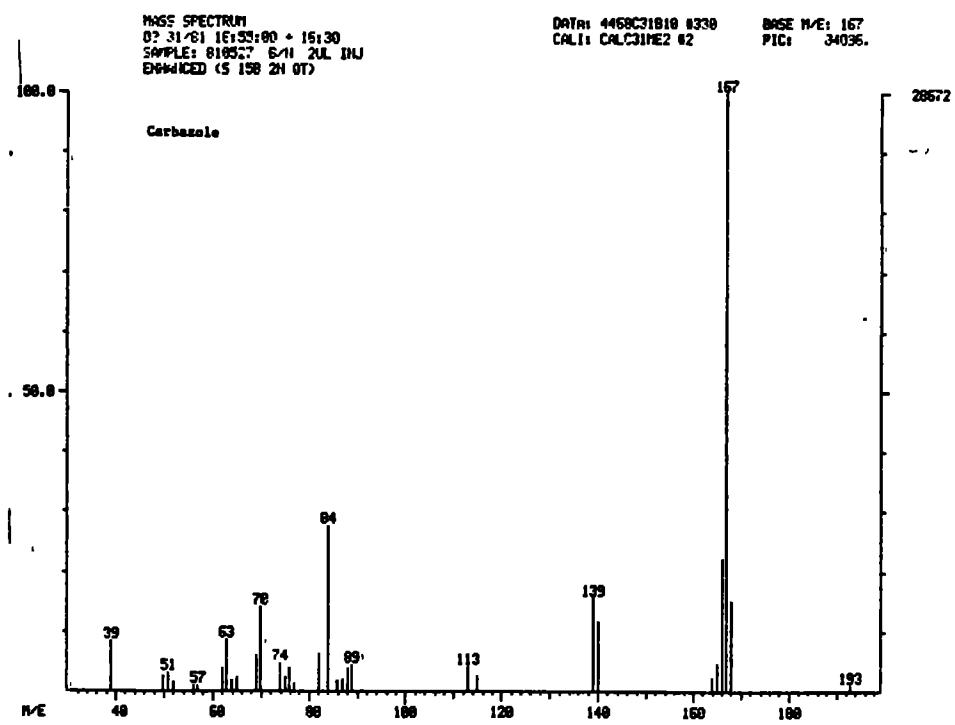


Figure 46. Mass spectrum of carbazole in sample 810527.

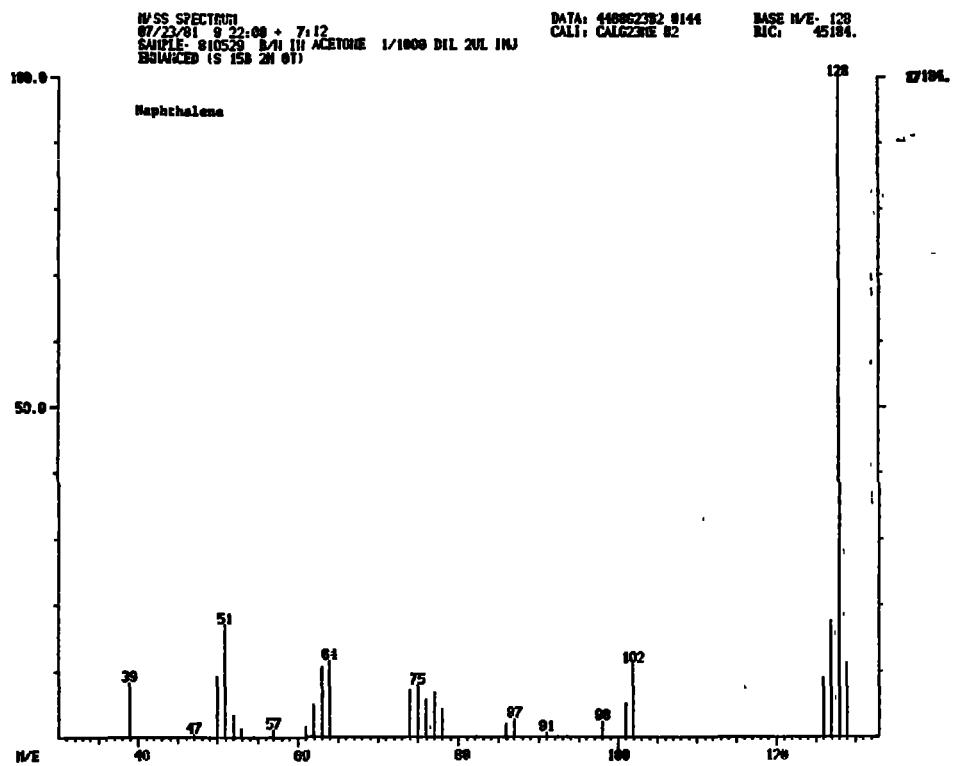


Figure 47. Mass spectrum of naphthalene in sample 810529.

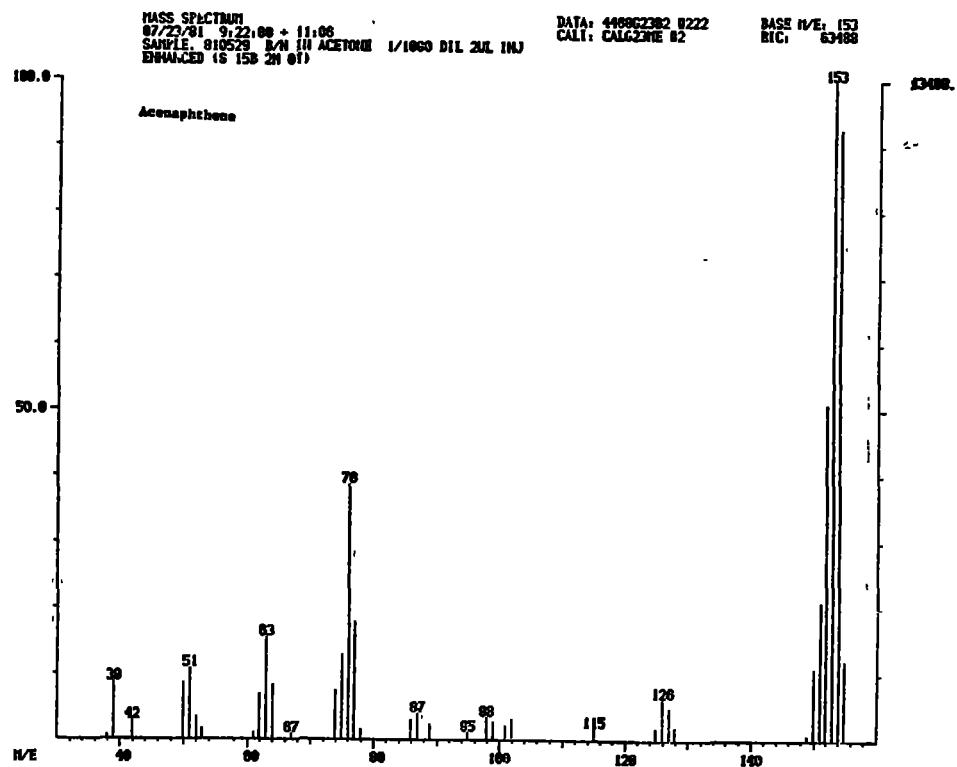


Figure 48. Mass spectrum of acenaphthene in sample 810529.

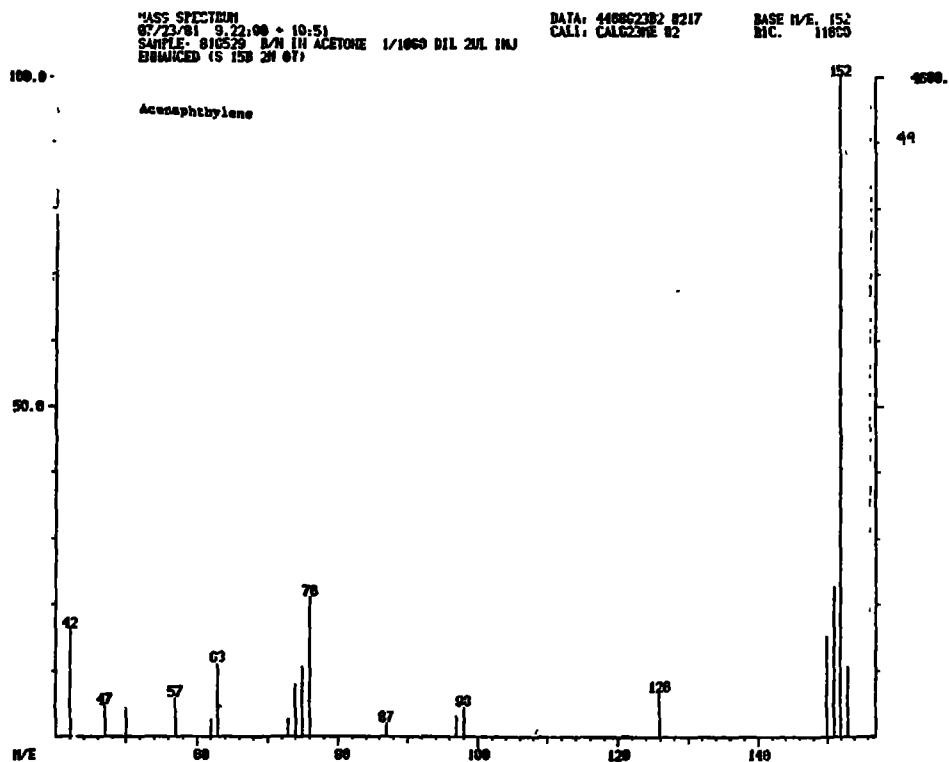


Figure 49. Mass spectrum of acenaphthylene in sample 810529.

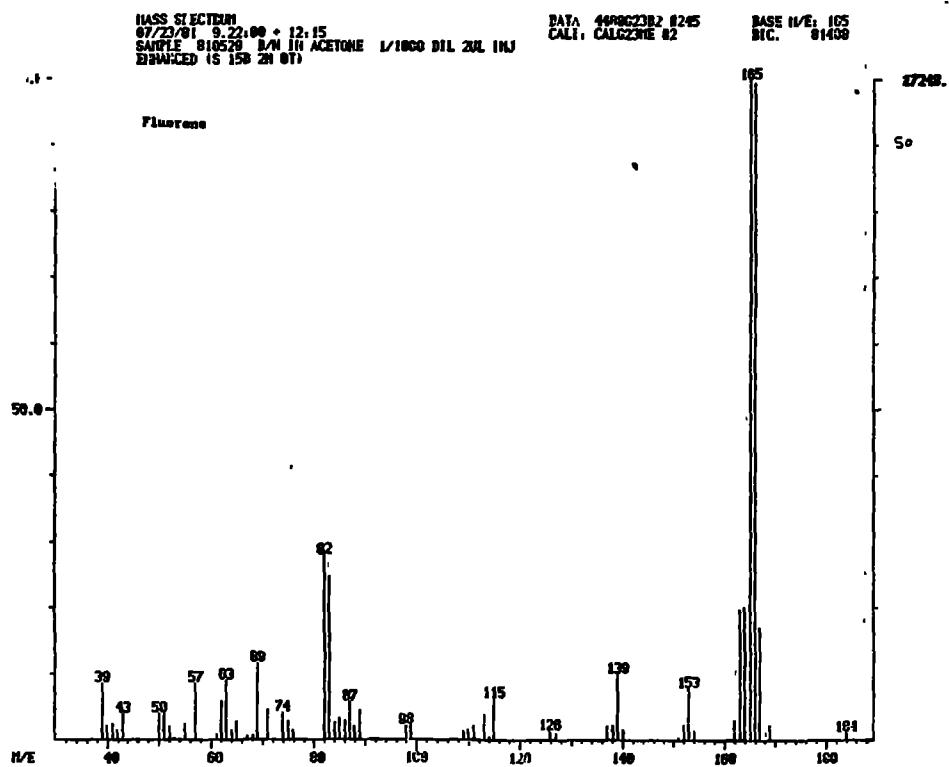


Figure 50. Mass spectrum of fluorene in sample 810529.

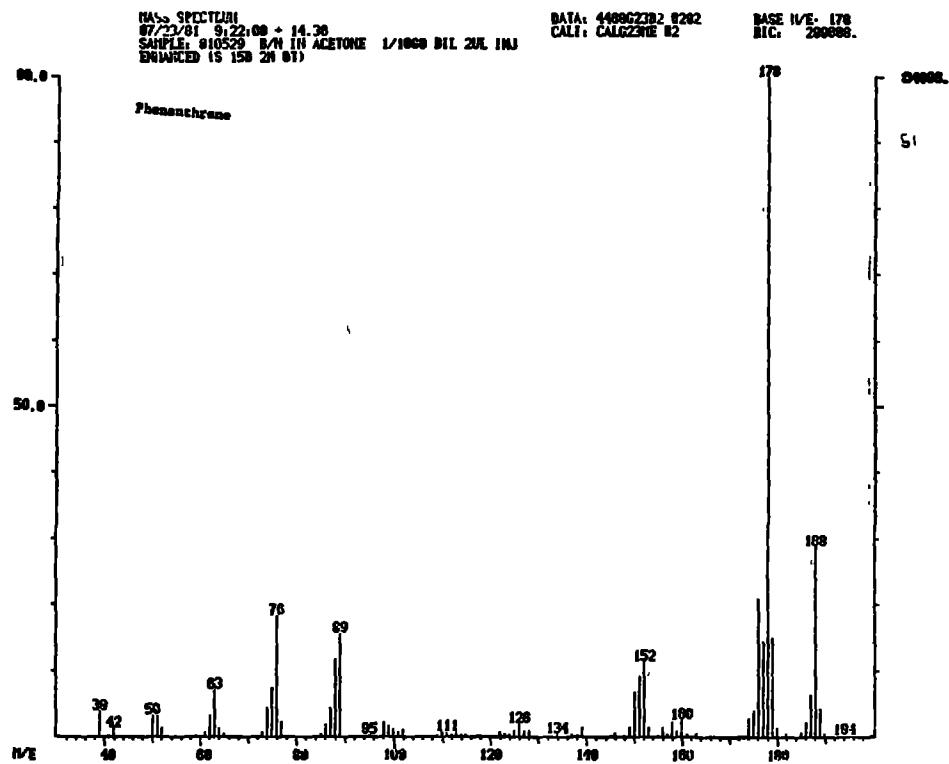


Figure 51. Mass spectrum of phenanthrene in sample 810529.

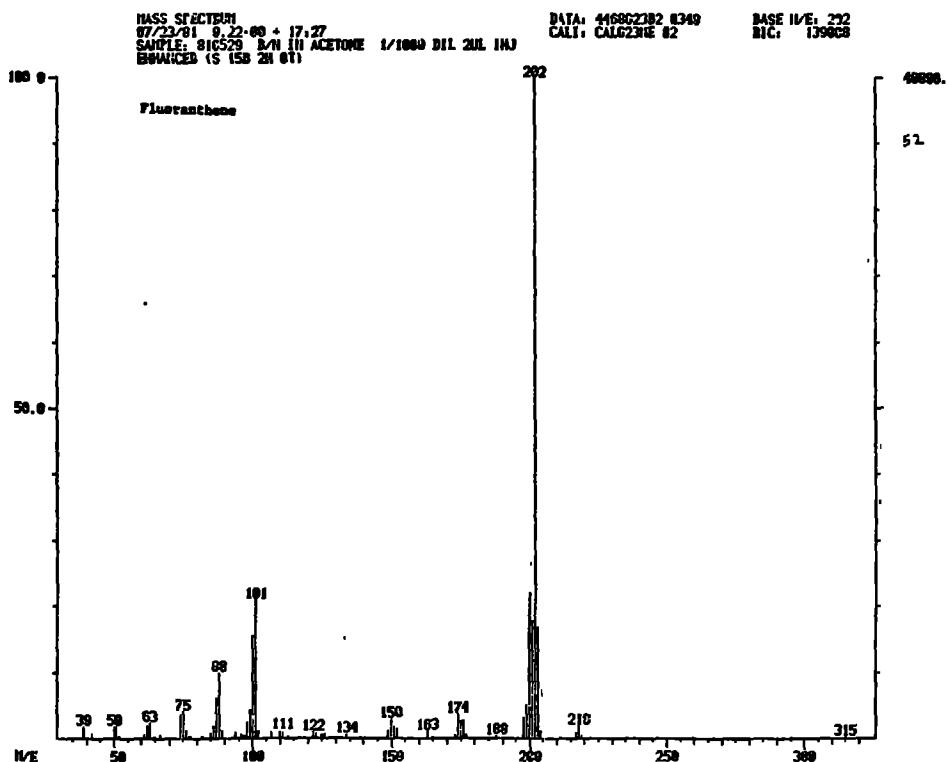


Figure 52. Mass spectrum of fluoranthene in sample 810529.

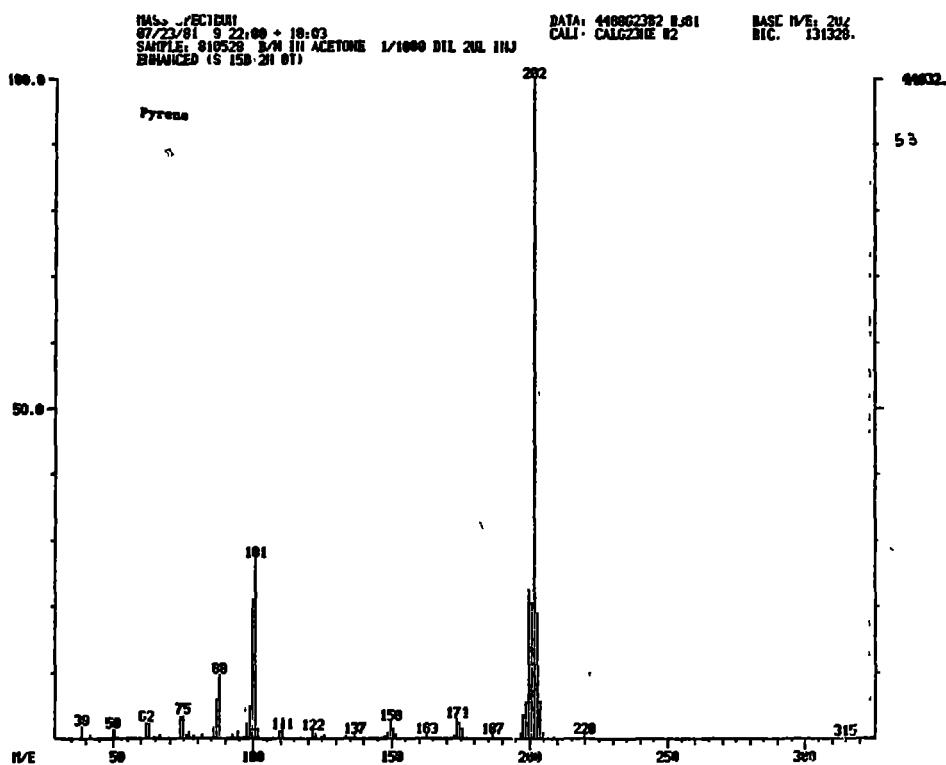


Figure 53. Mass spectrum of pyrene in sample 810529.

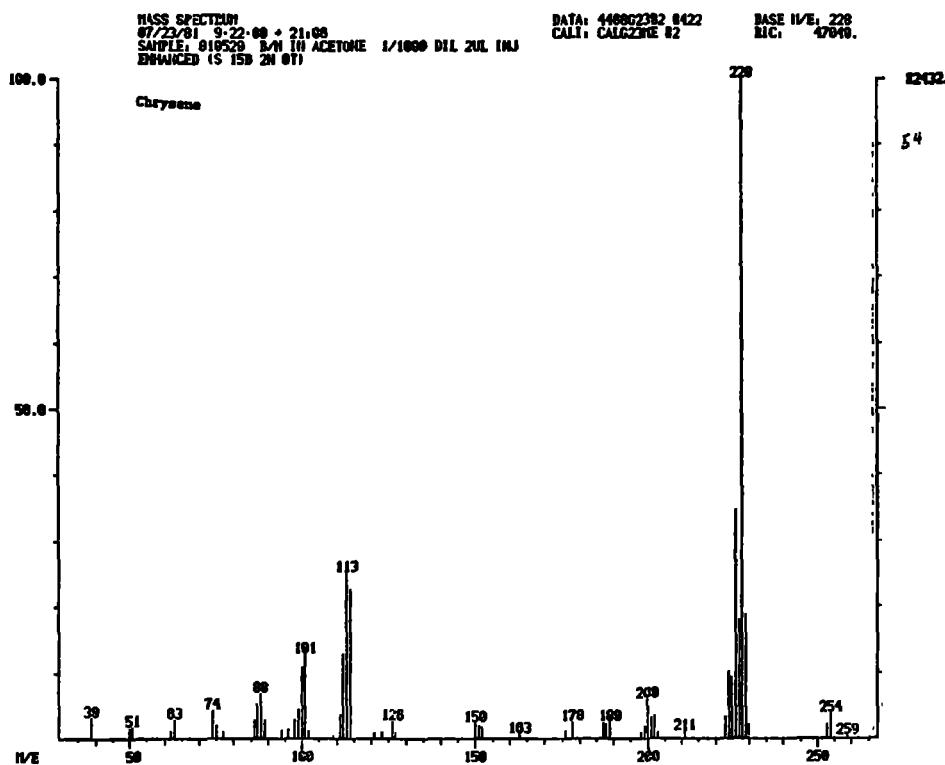


Figure 54. Mass spectrum of chrysene in sample 810529.

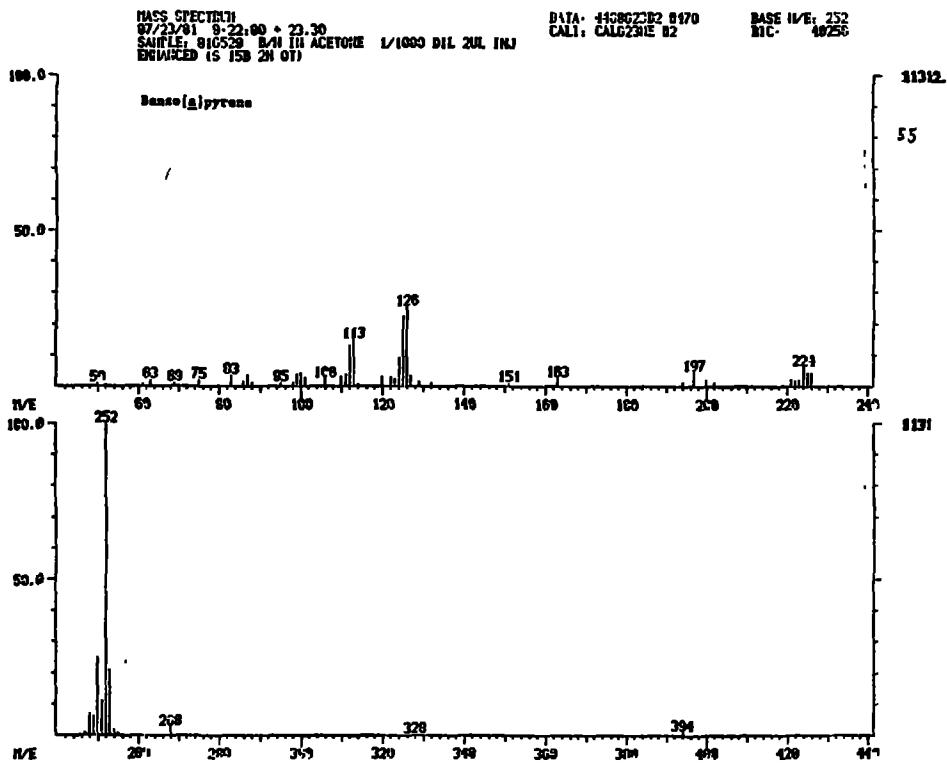


Figure 55. Mass spectrum of benzo[a]pyrene in sample 810529.

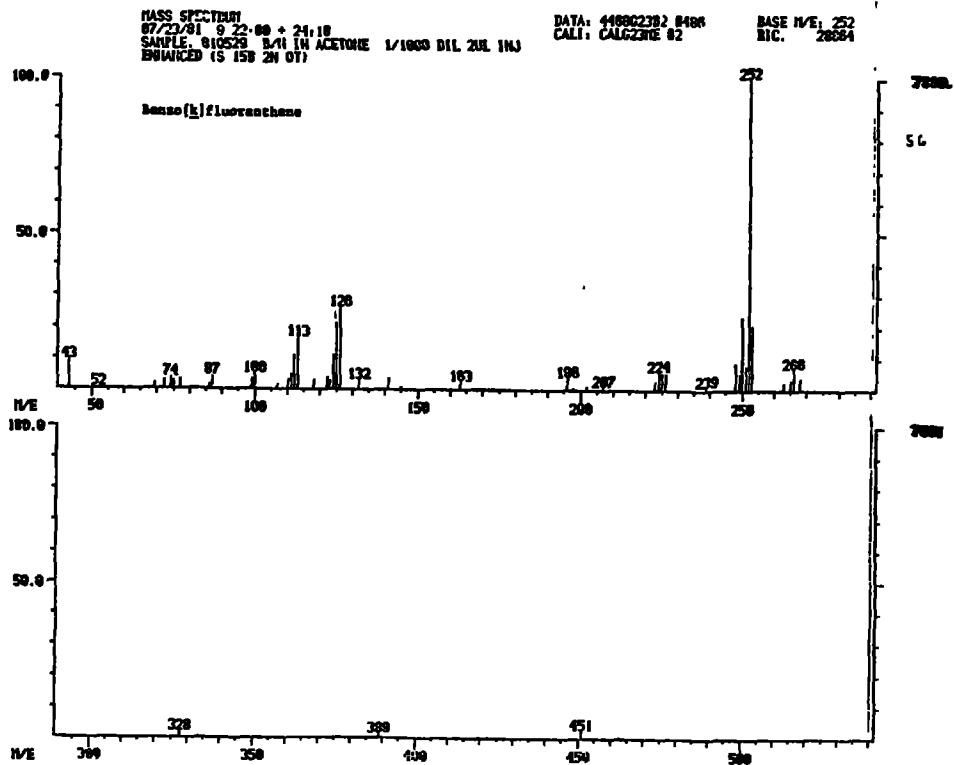


Figure 56. Mass spectrum of benzo[k]fluoranthene in sample 810529.

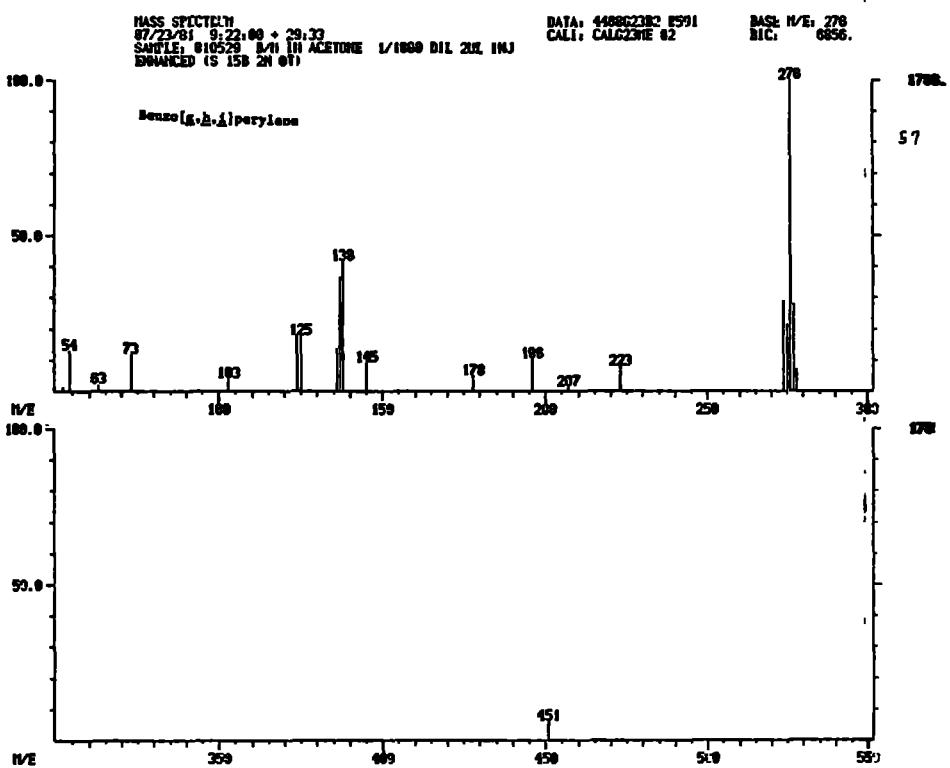


Figure 57. Mass spectrum of benzo[g,h,i]perylene in sample 810529.

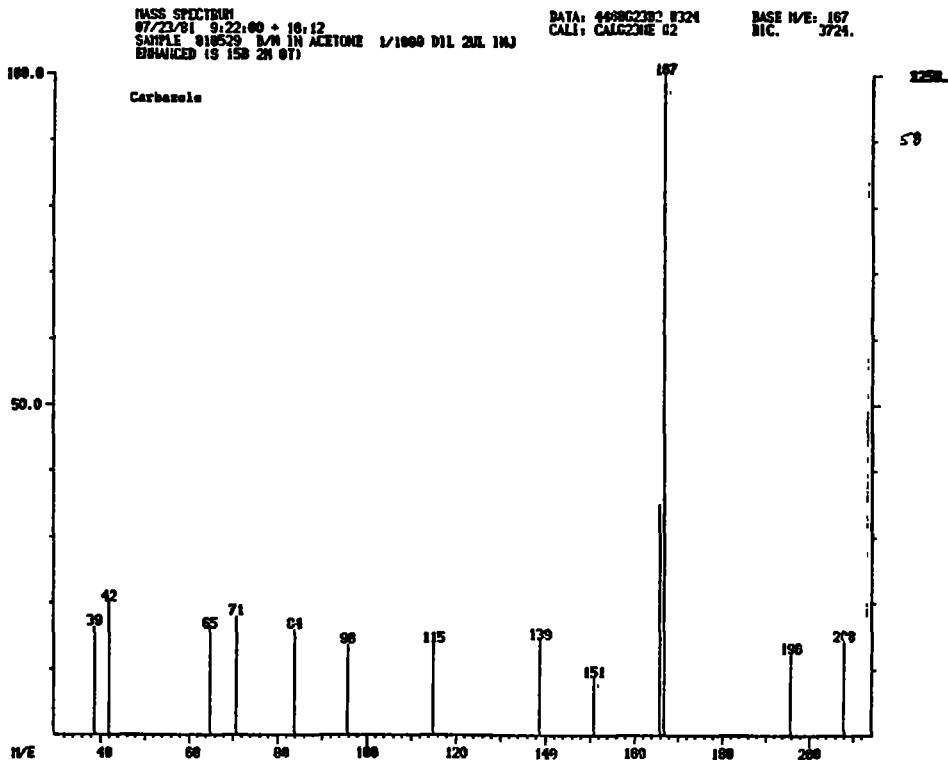


Figure 58. Mass spectrum of carbazole in sample 810529.

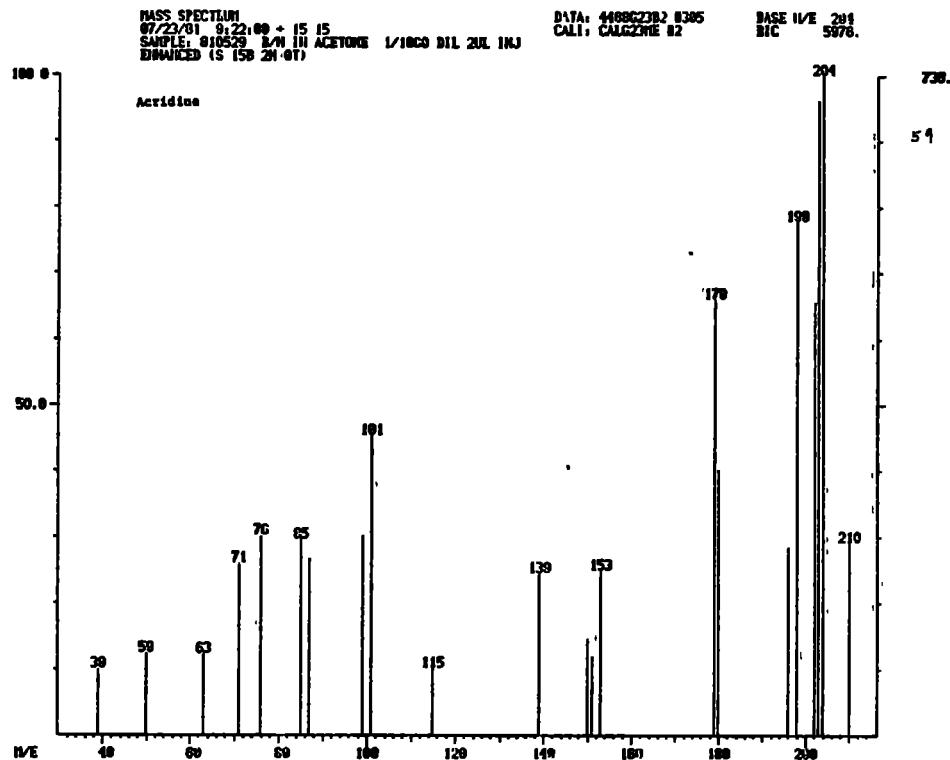


Figure 59. Mass spectrum of acridine in sample 810529.

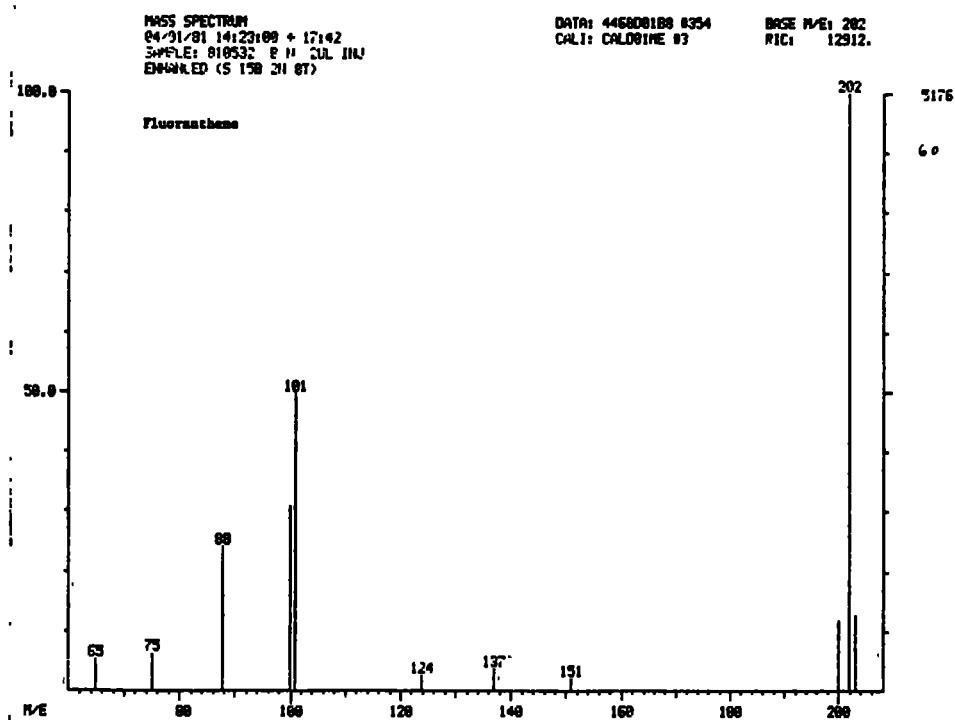


Figure 60. Mass spectrum of fluoranthene in sample 810532.

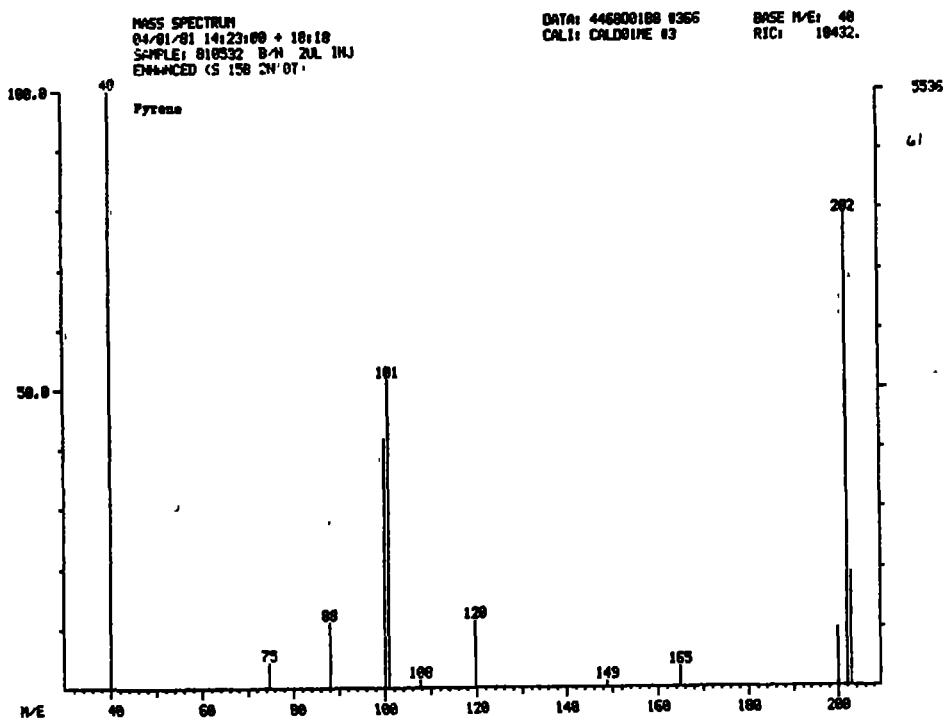


Figure 61. Mass spectrum of pyrene in sample 810532

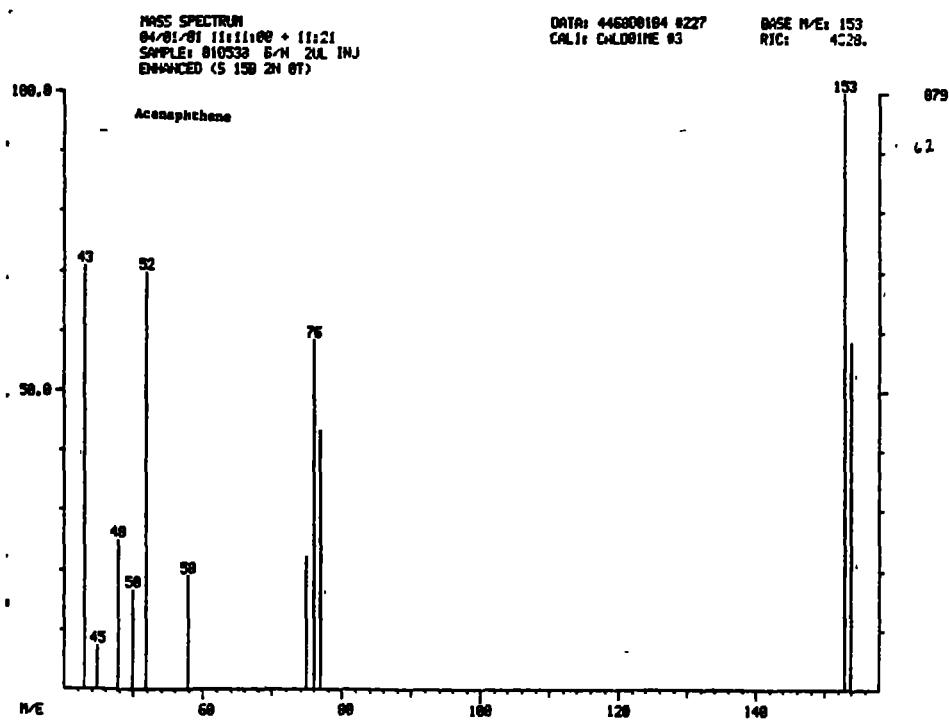


Figure 62. Mass spectrum of acenaphthene in sample 810538.

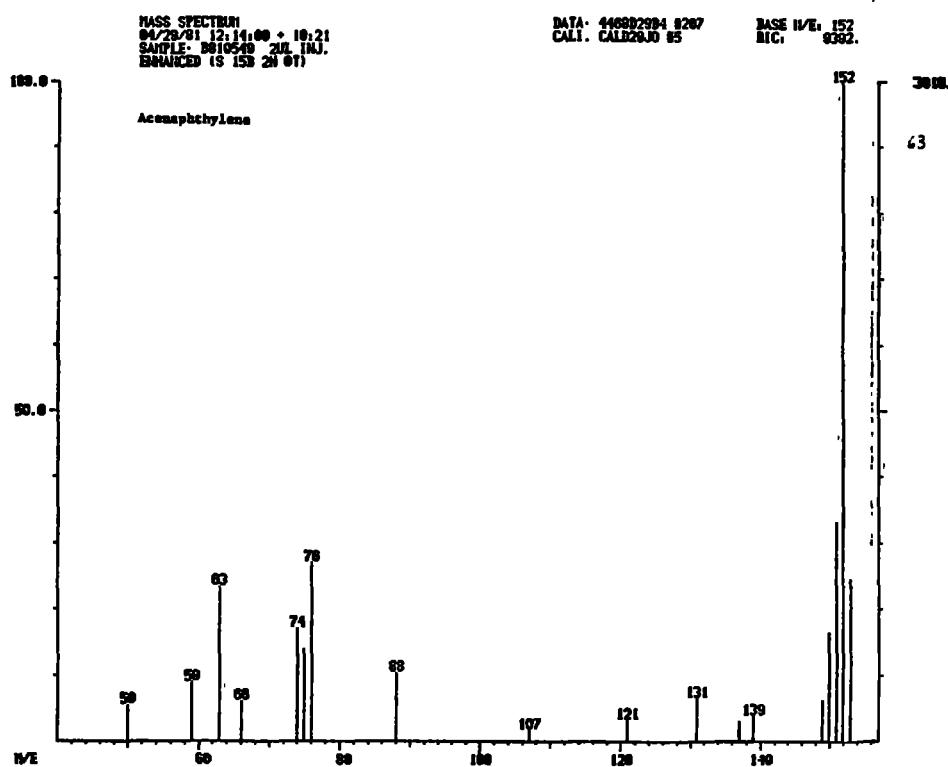


Figure 63. Mass spectrum of acenaphthylene in sample 810549.

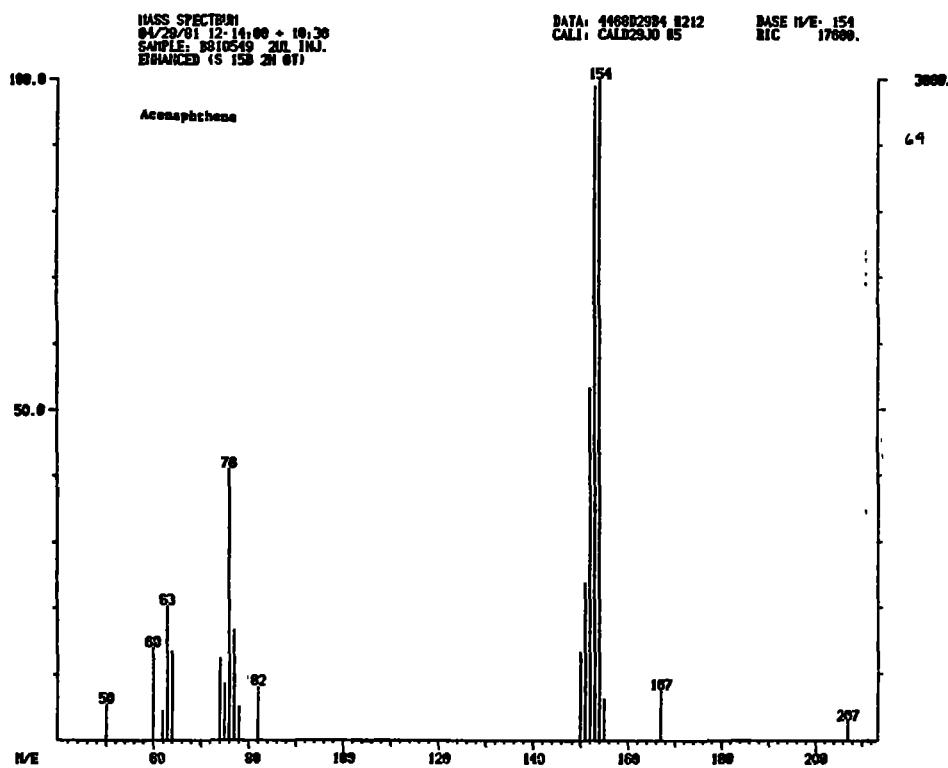


Figure 64. Mass spectrum of acenaphthene in sample 810549.

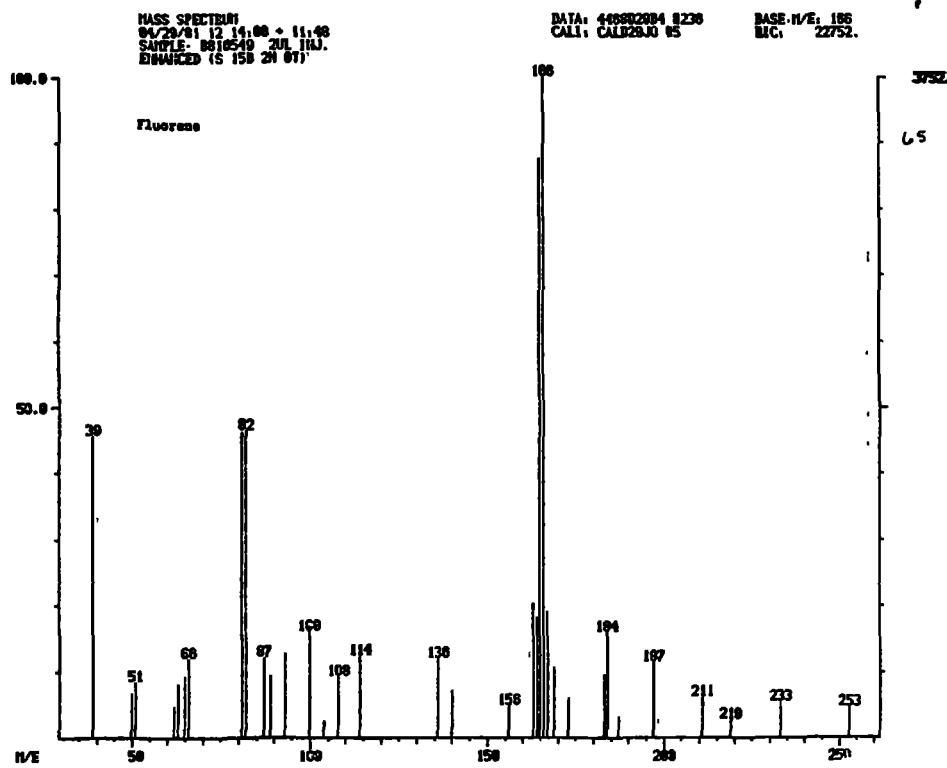


Figure 65. Mass spectrum of fluorene in sample 810549.

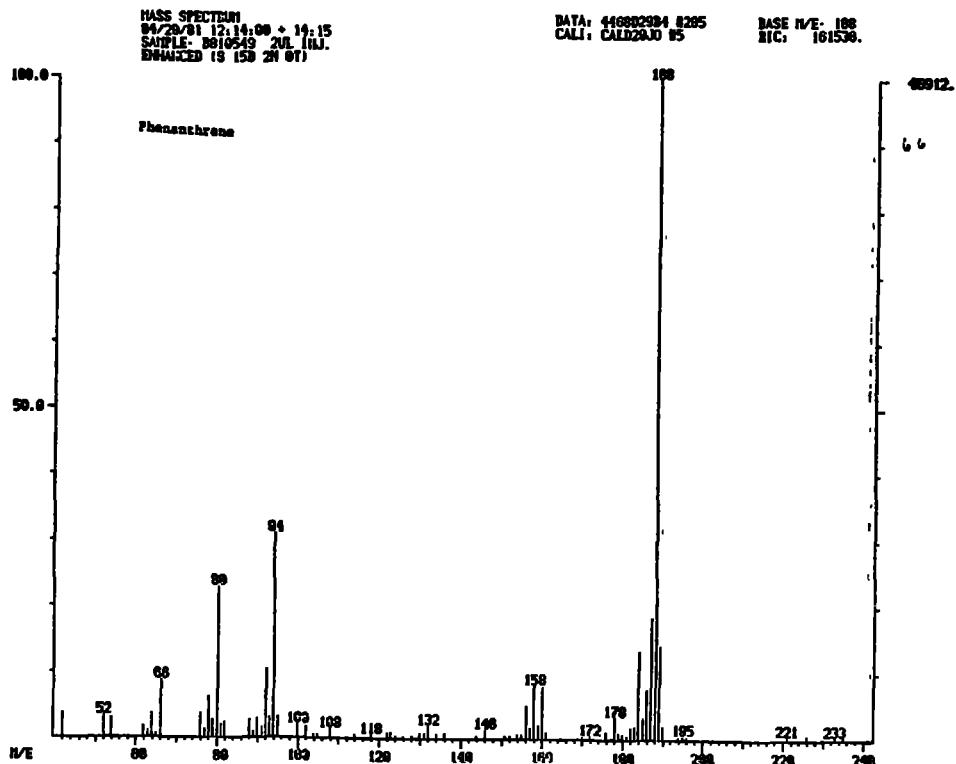


Figure 66. Mass spectrum of phenanthrene in sample 810549.

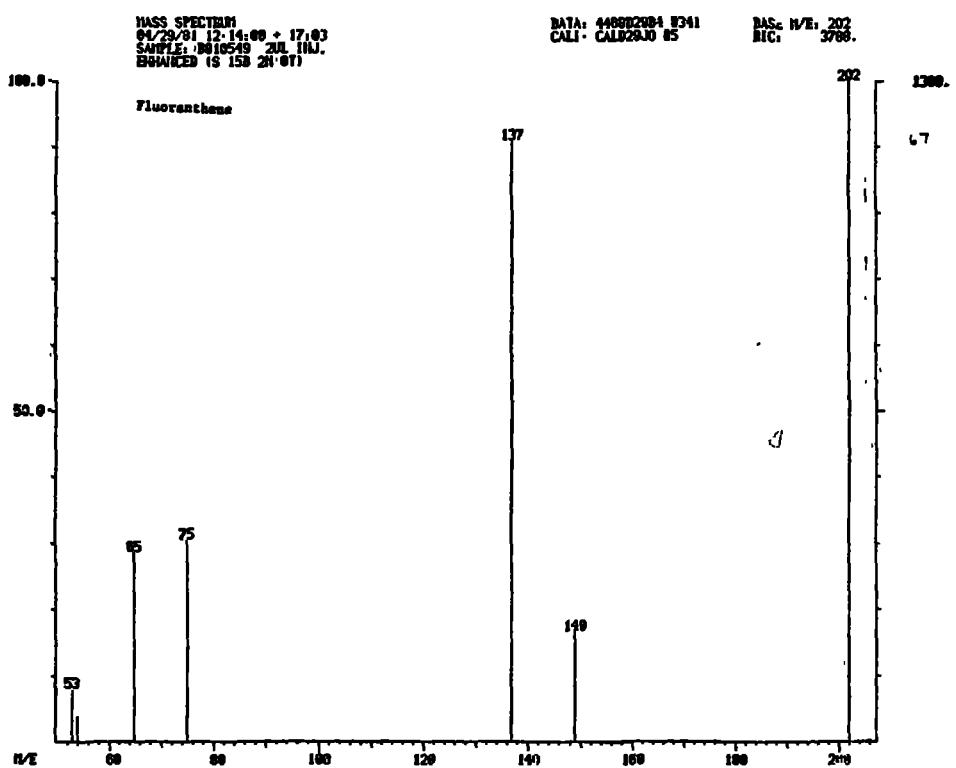


Figure 67. Mass spectrum of fluoranthene in sample 810549.

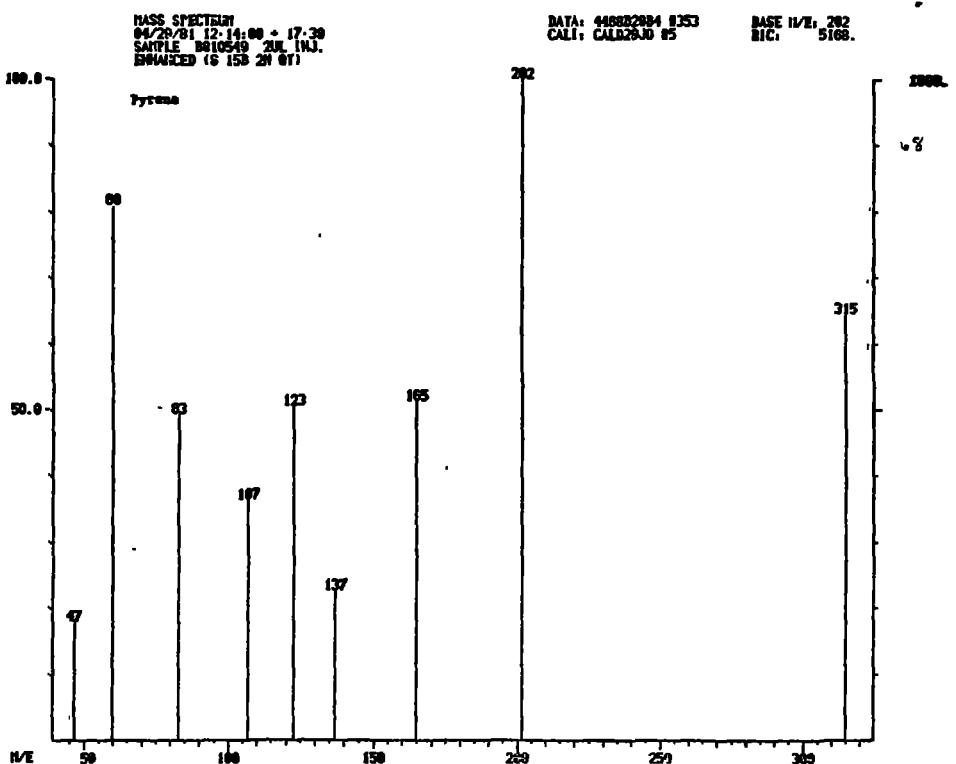


Figure 68. Mass spectrum of pyrene in sample 810549.

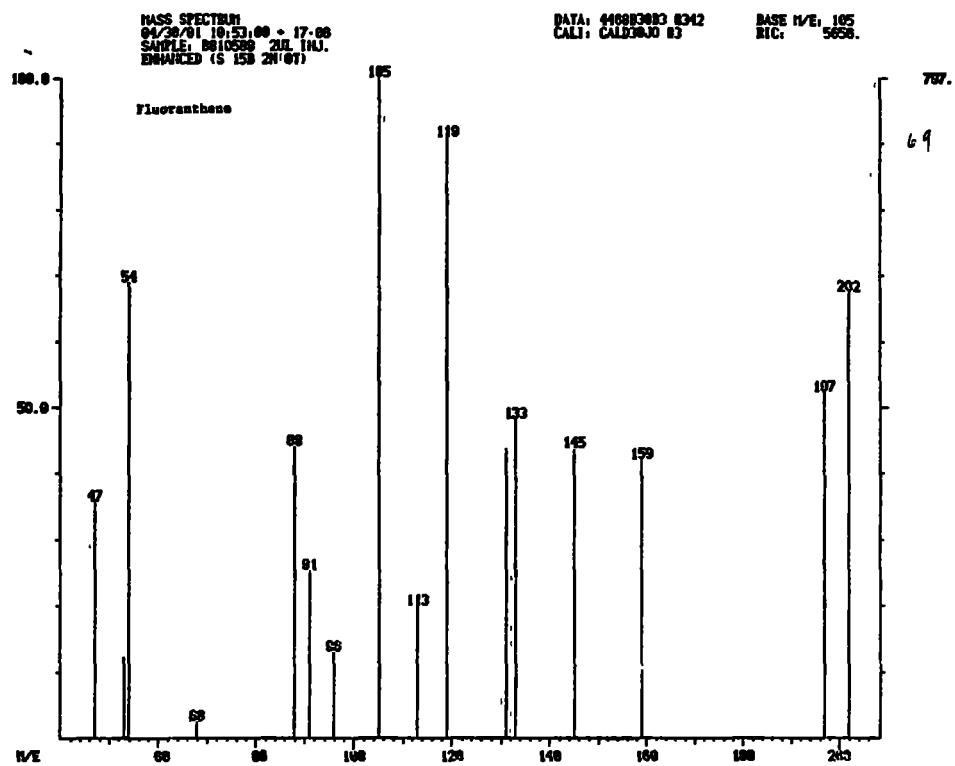


Figure 69. Mass spectrum of fluoranthene in sample 810589.

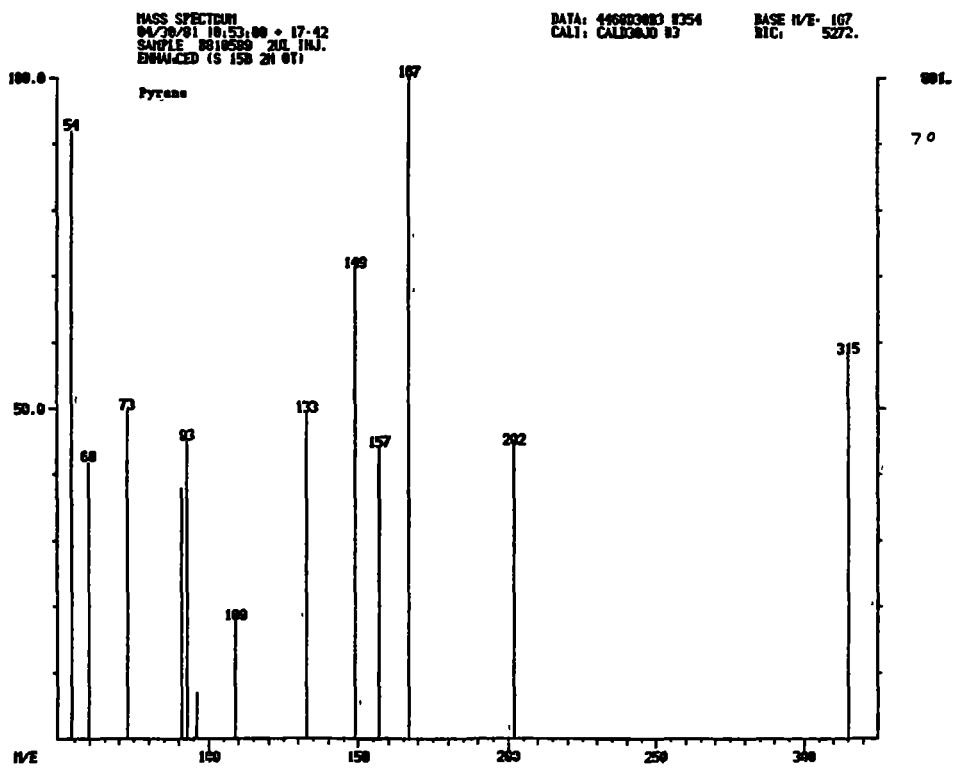


Figure 70. Mass spectrum of pyrene in sample 810589.

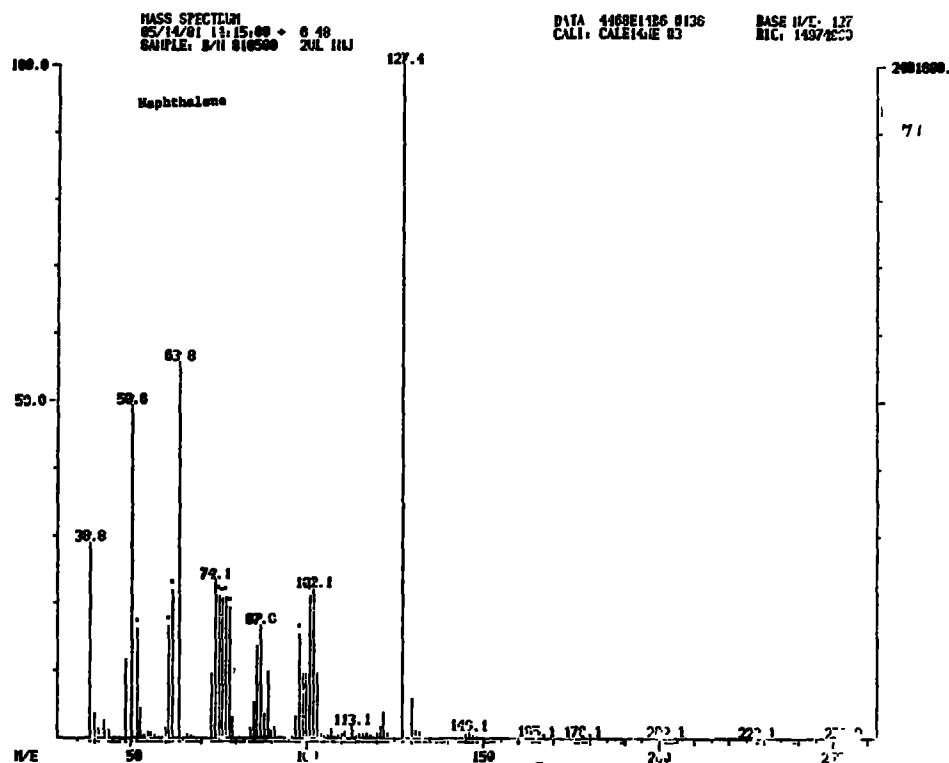


Figure 71. Mass spectrum of naphthalene in sample 810590.

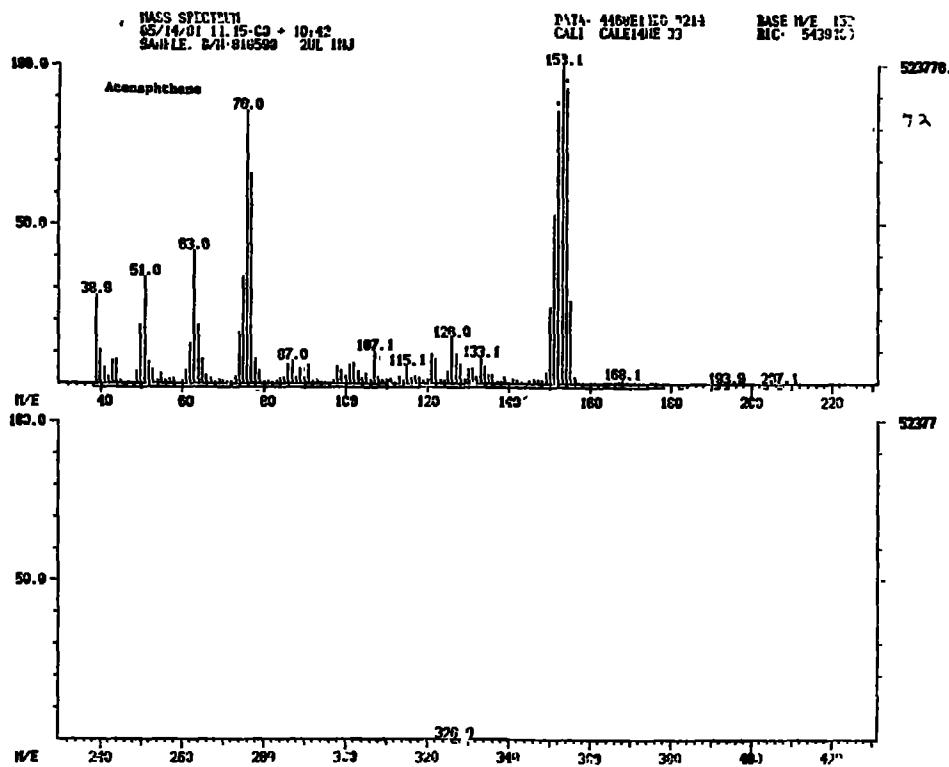


Figure 72. Mass spectrum of acenaphthene in sample 810590.

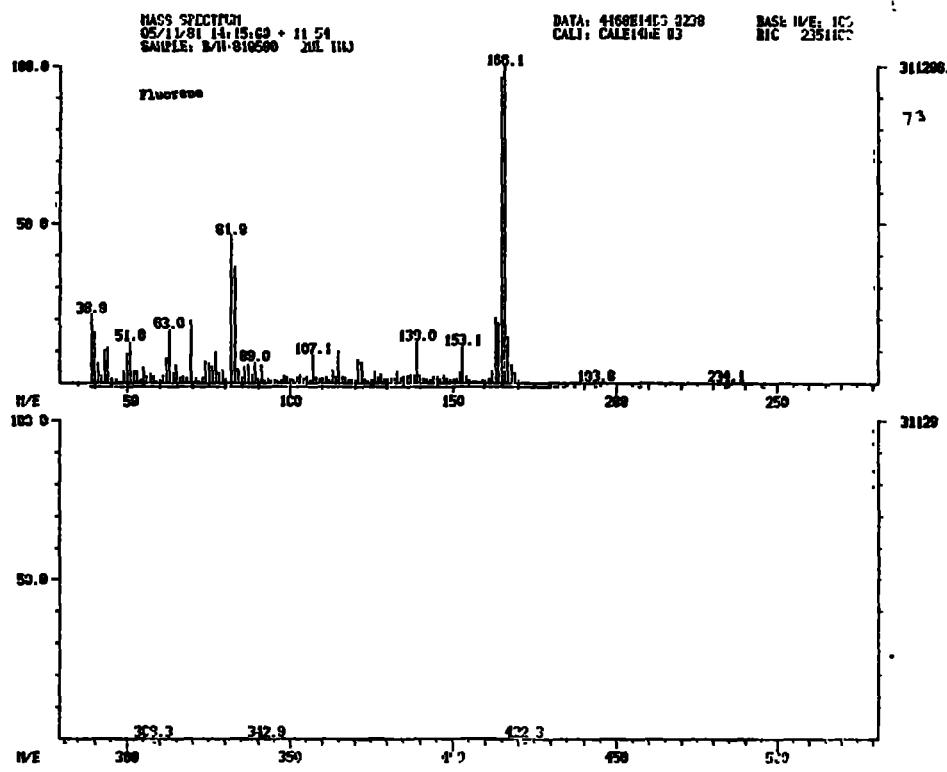


Figure 73. Mass spectrum of fluorene in sample 810590.

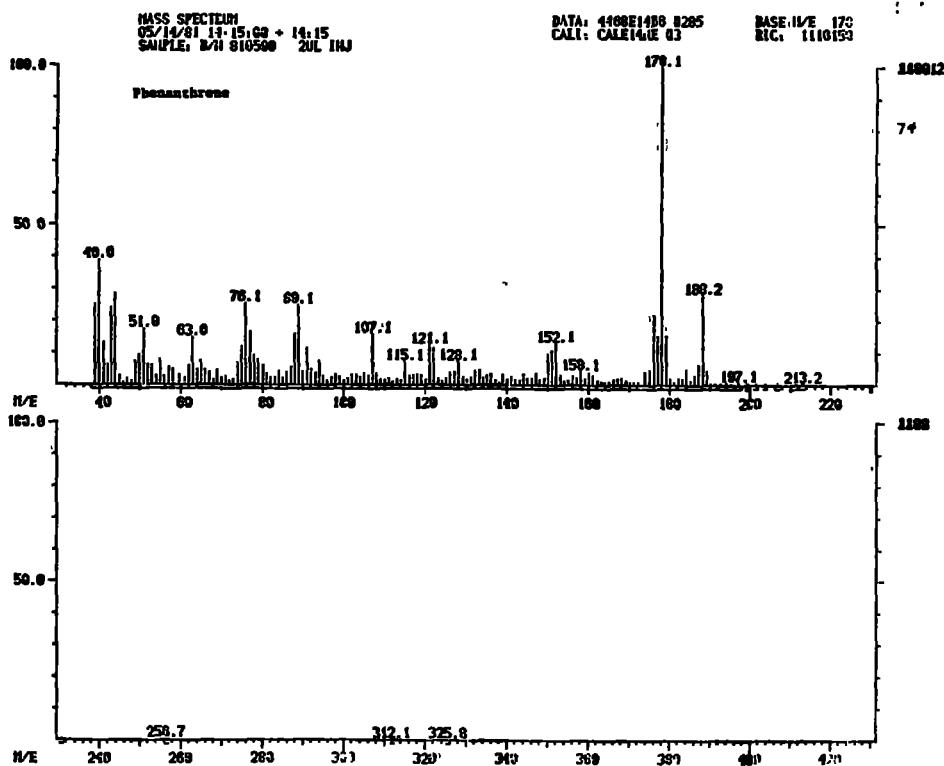


Figure 74. Mass spectrum of phenanthrene in sample 810590.

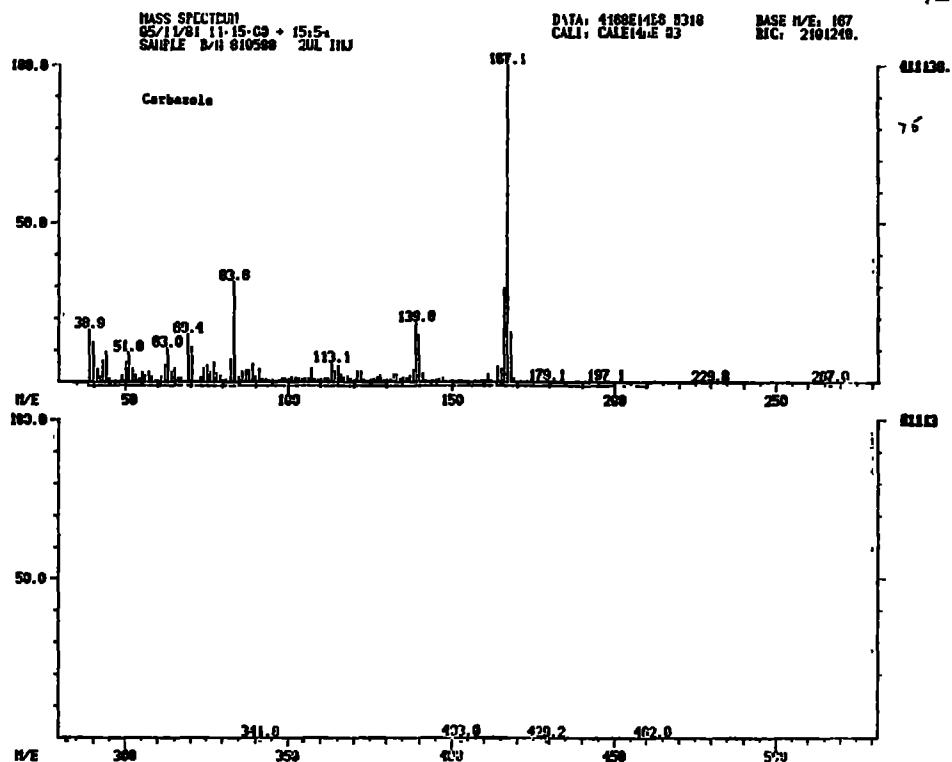


Figure 75. Mass spectrum of carbazole in sample 810590.

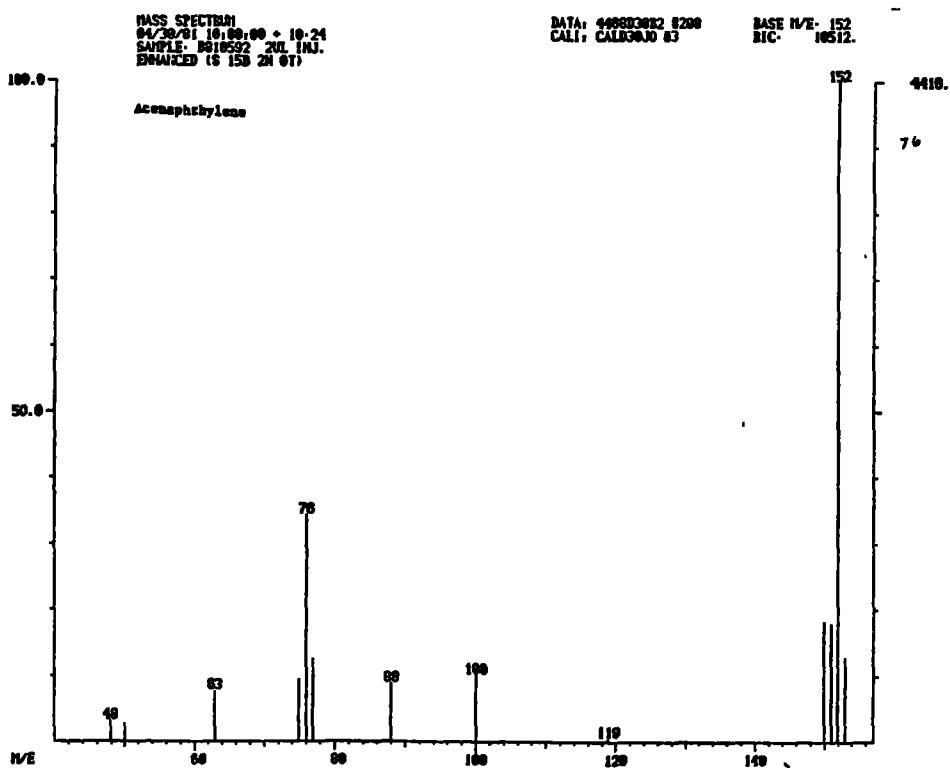


Figure 76. Mass spectrum of acenaphthylene in sample 810592.

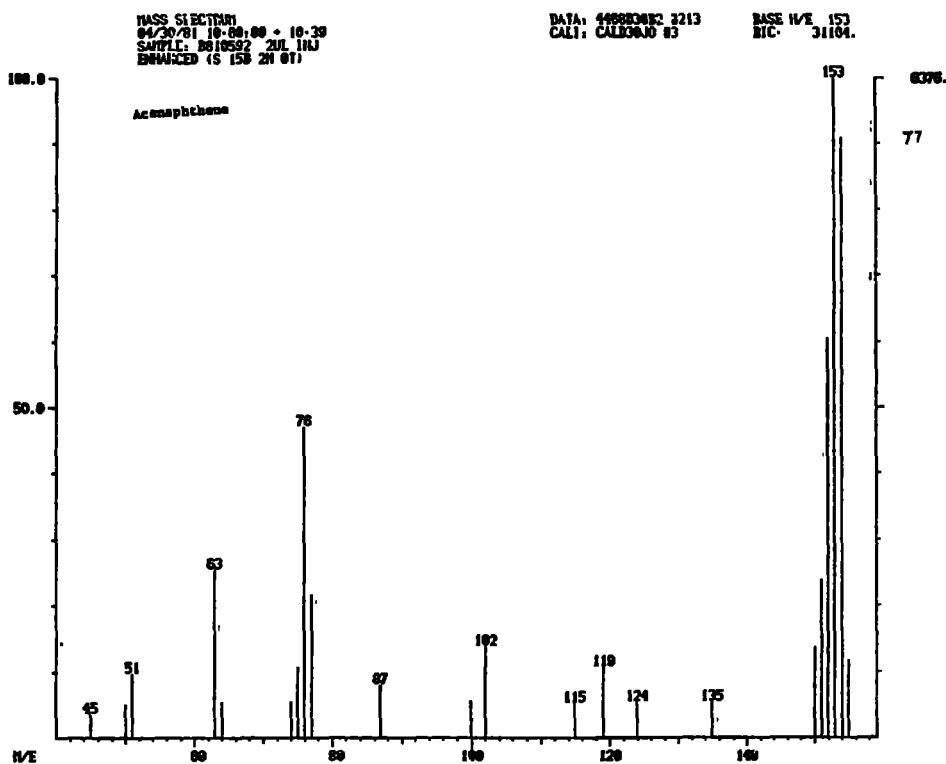


Figure 77. Mass spectrum of acenaphthene in sample 810592.

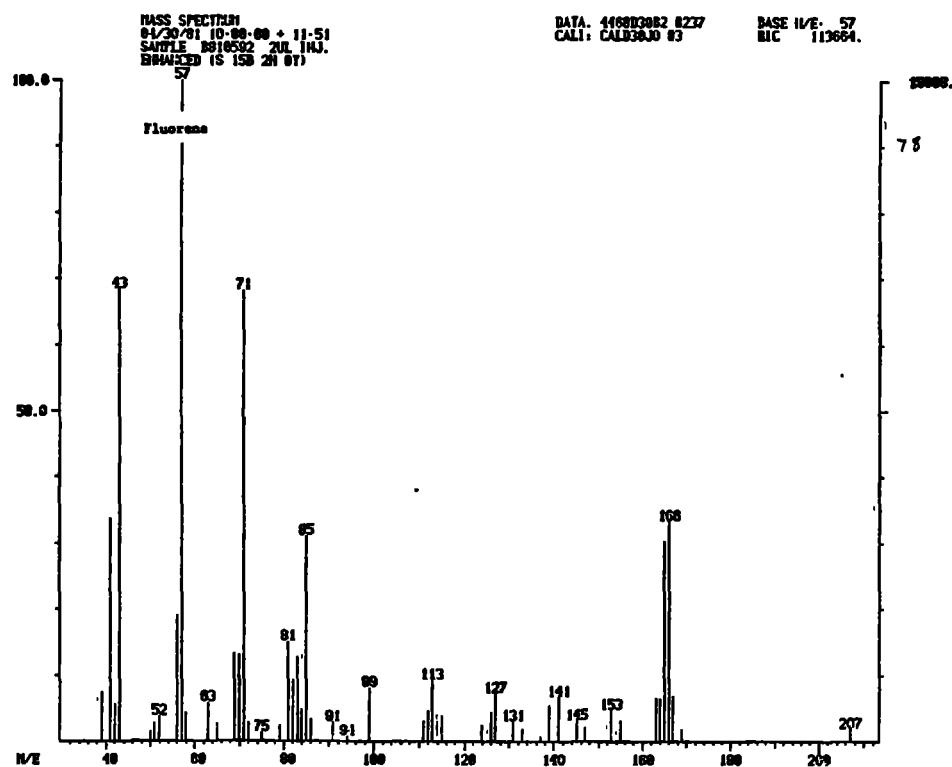


Figure 78. Mass spectrum of fluorene in sample 810592.

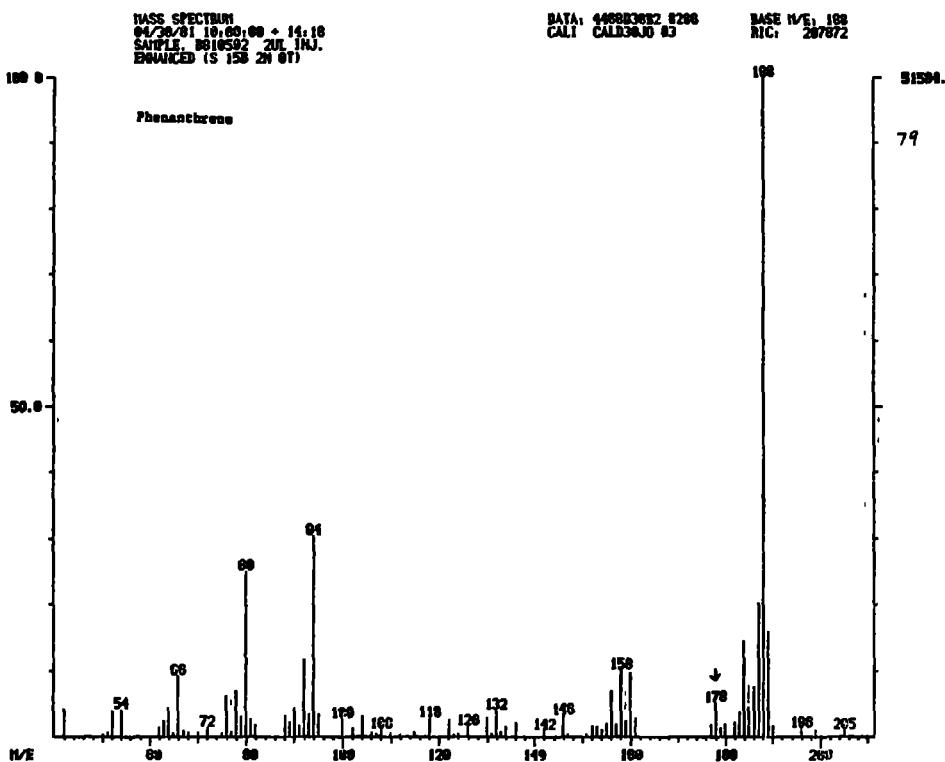


Figure 79. Mass spectrum of phenanthrene in sample 810592.

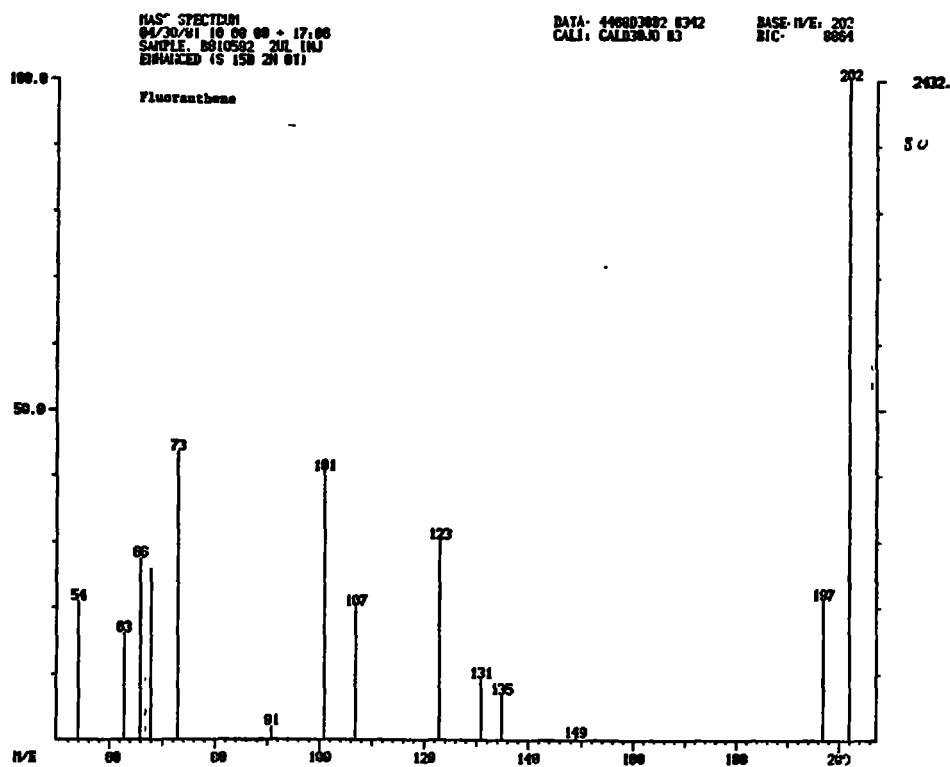


Figure 80. Mass spectrum of fluoranthene in sample 810592.

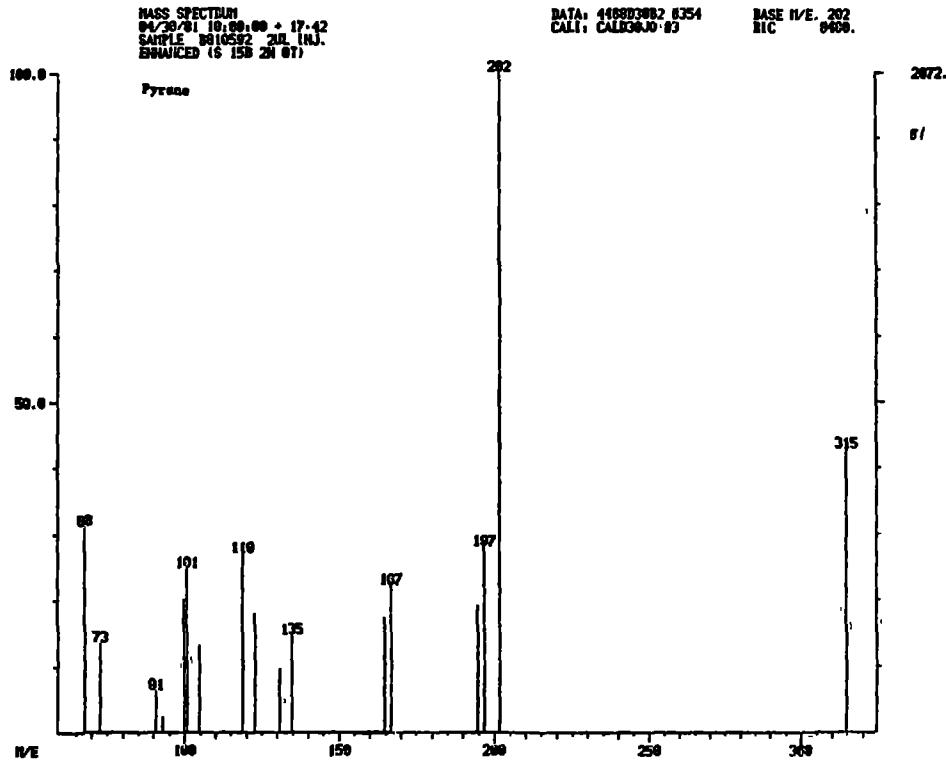


Figure 81. Mass spectrum of pyrene in sample 810592.

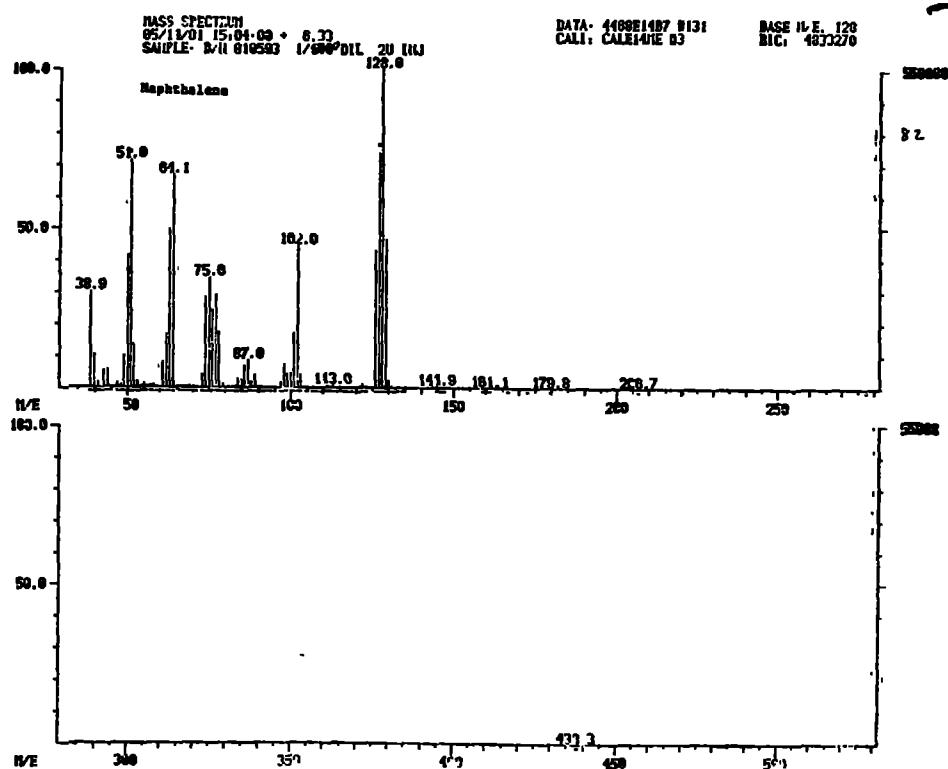


Figure 82. Mass spectrum of naphthalene in sample 810593.

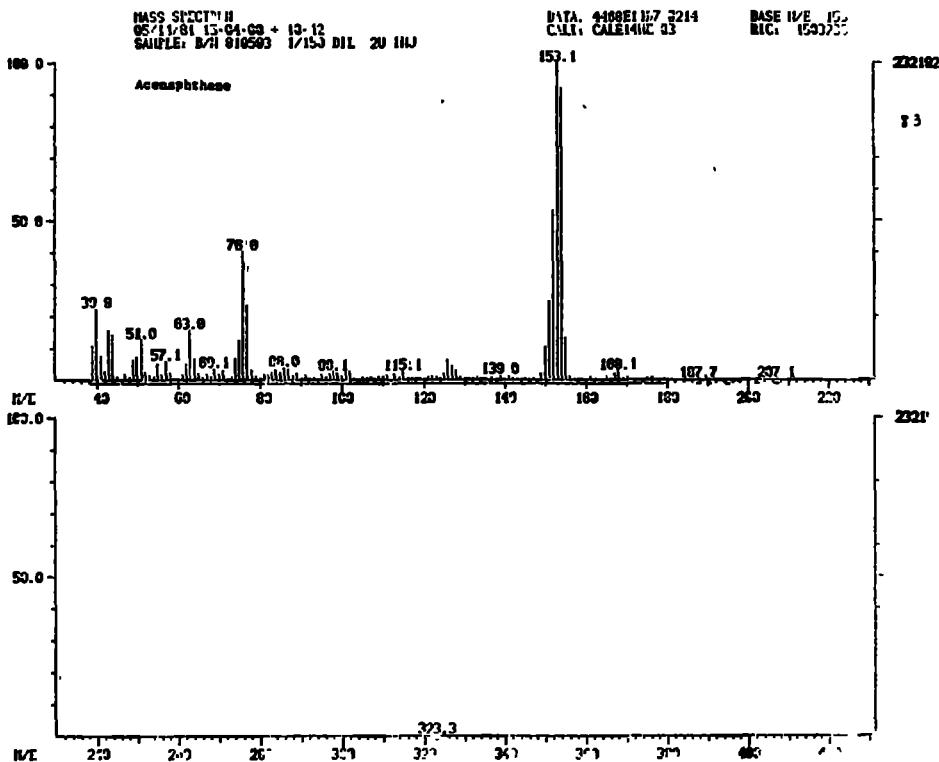


Figure 83. Mass spectrum of acenaphthene in sample 810593.

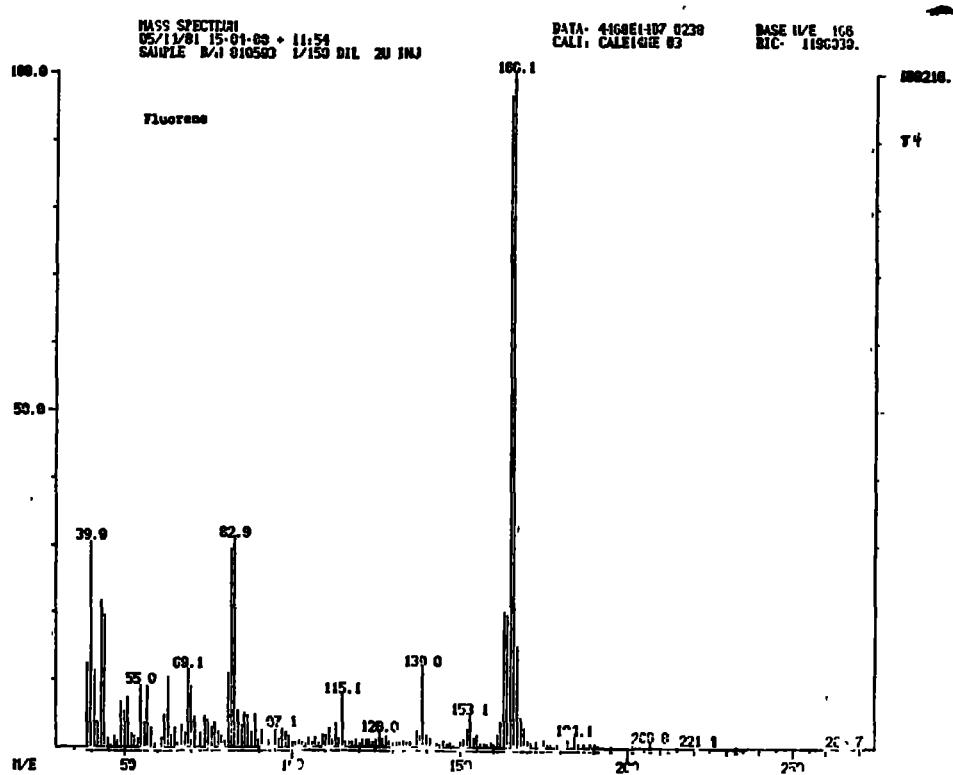


Figure 84. Mass spectrum of fluorene in sample 810593.

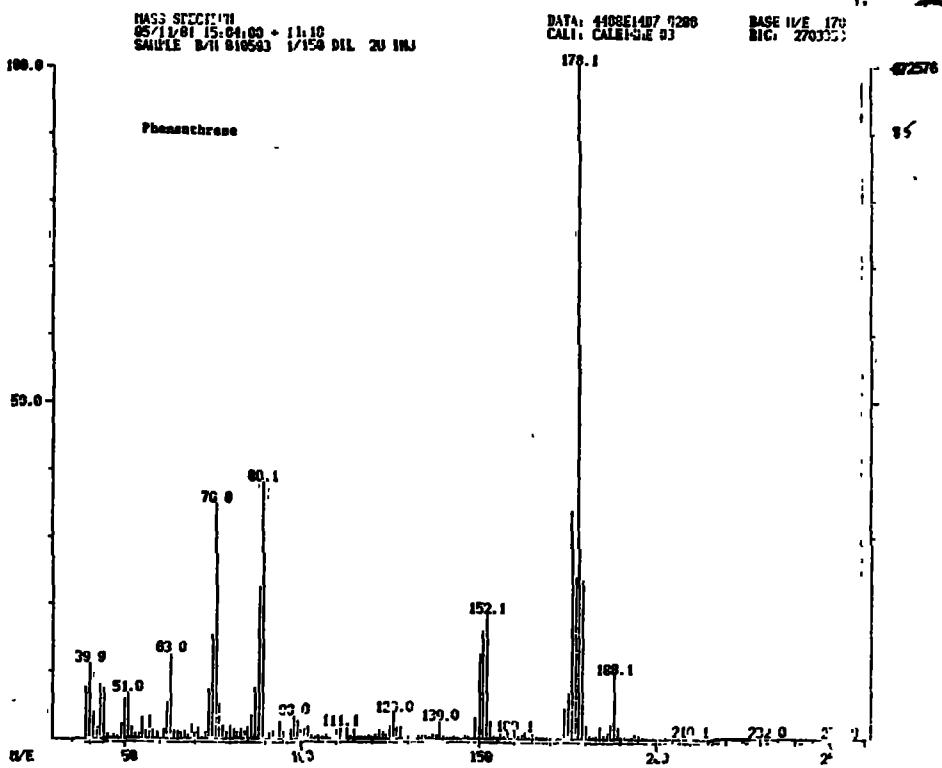


Figure 85. Mass spectrum of phenanthrene in sample 810593.

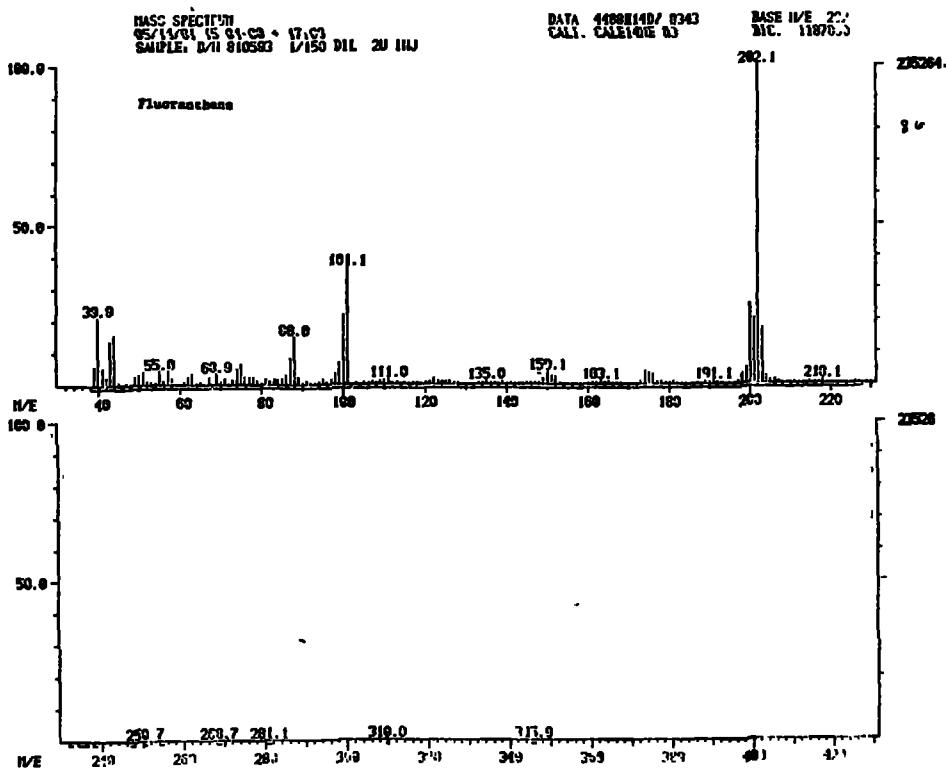


Figure 86. Mass spectrum of fluoranthene in sample 810593.

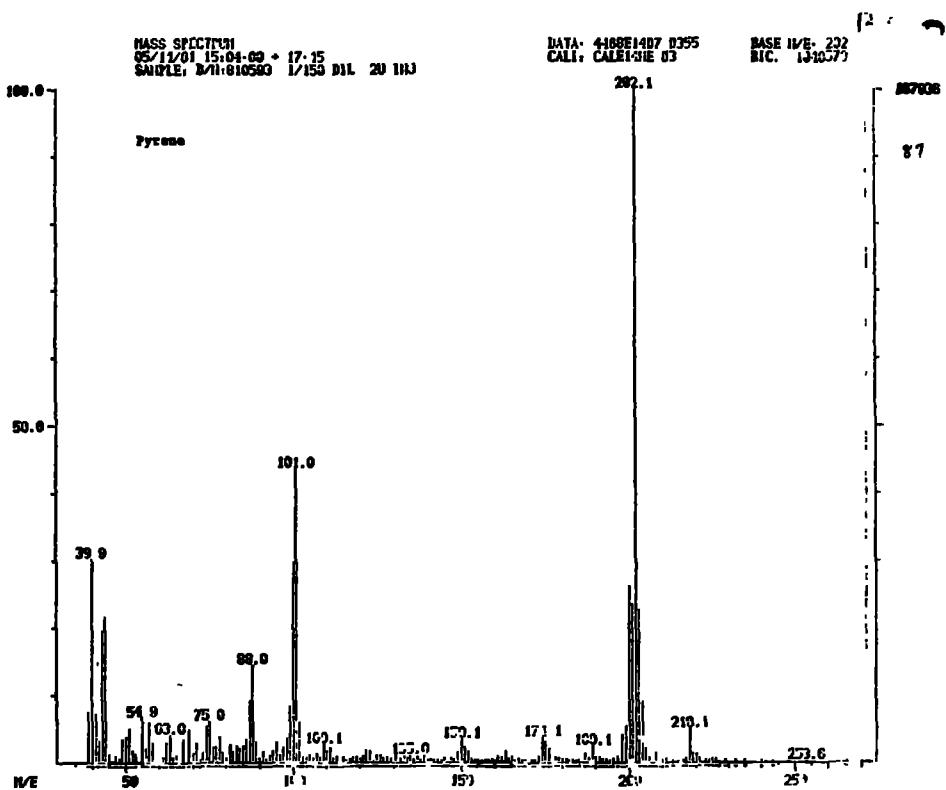


Figure 87. Mass spectrum of pyrene in sample 810593.

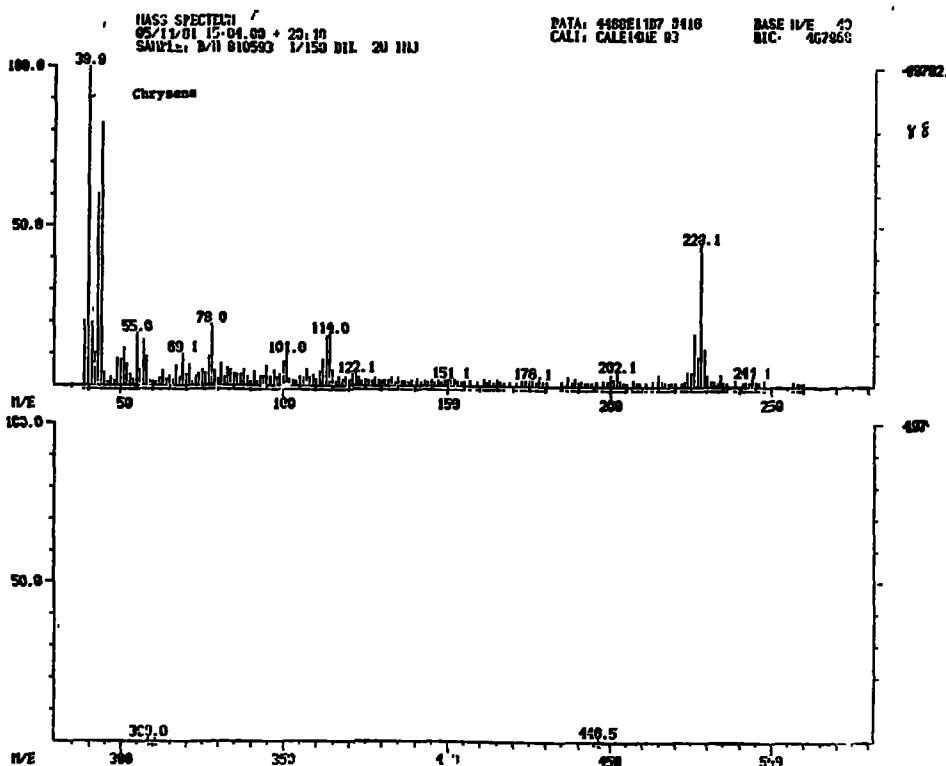


Figure 88. Mass spectrum of chrysene in sample 810593.

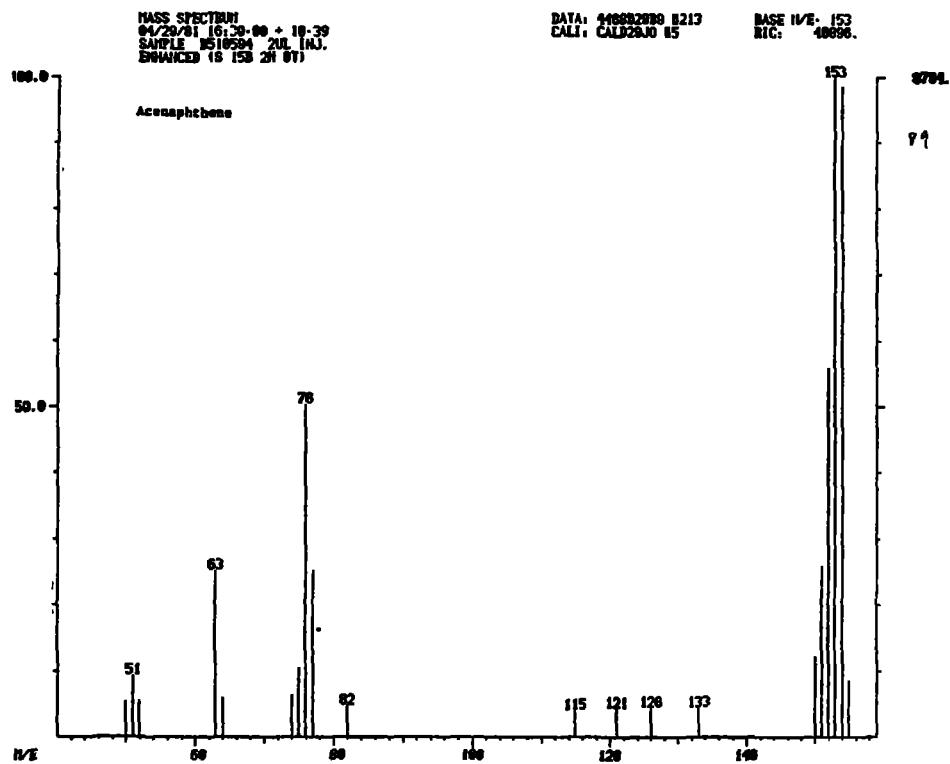


Figure 89. Mass spectrum of acenaphthene in sample 810594.

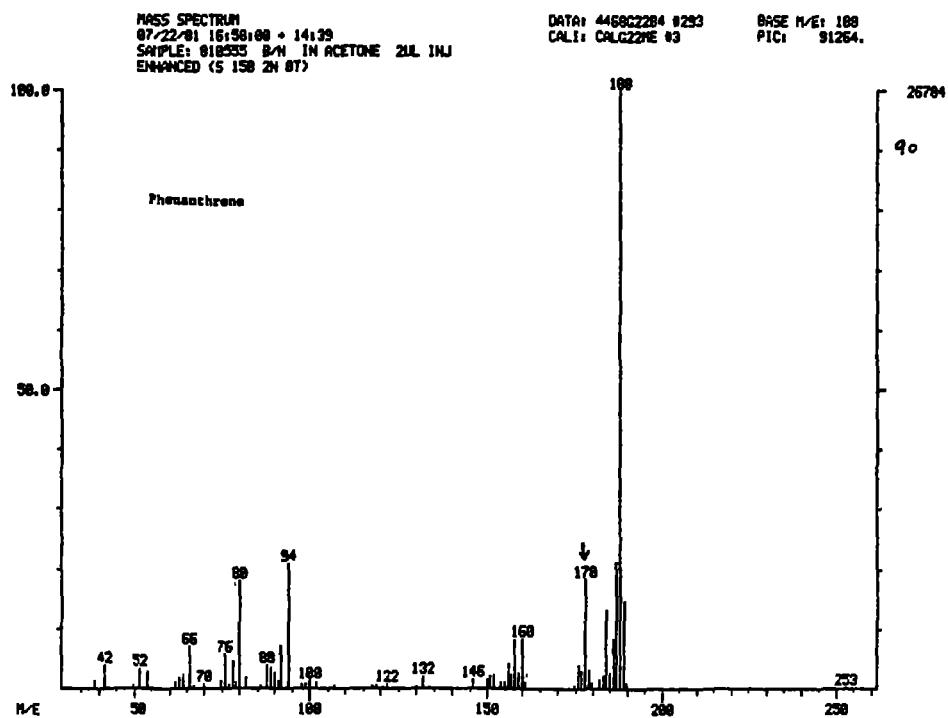


Figure 90. Mass spectrum of phenanthrene in sample 810555.

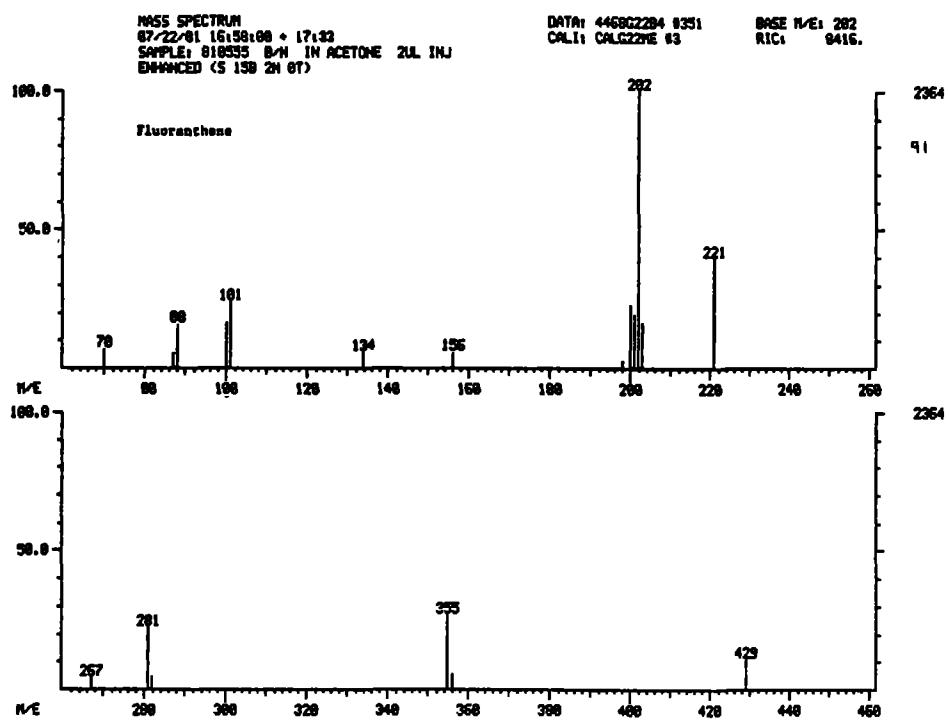


Figure 91. Mass spectrum of fluoranthene in sample 810555.

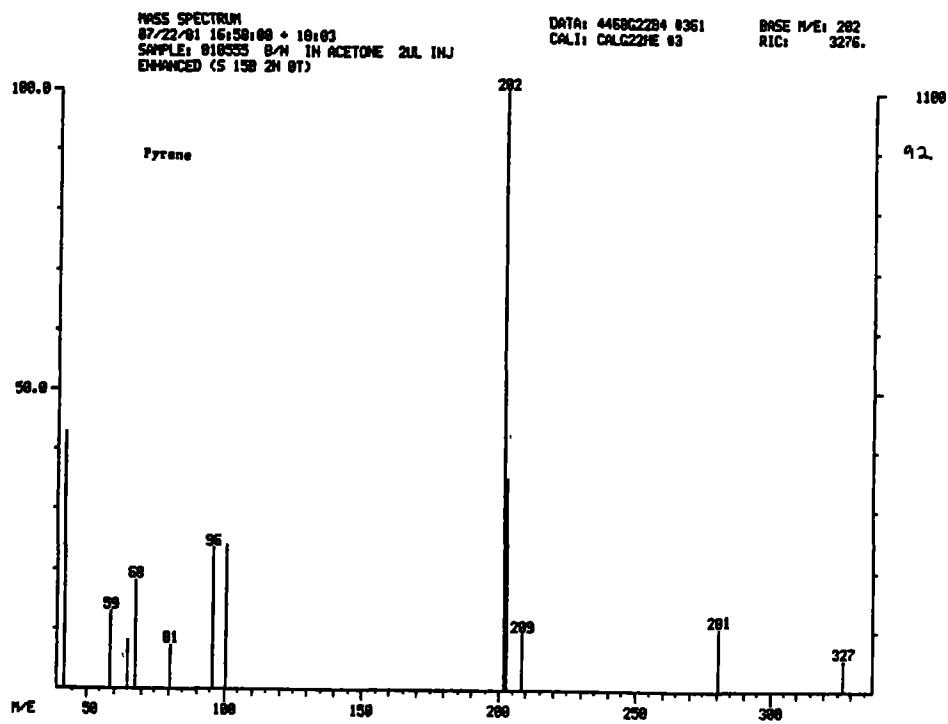


Figure 92. Mass spectrum of pyrene in sample 810555.

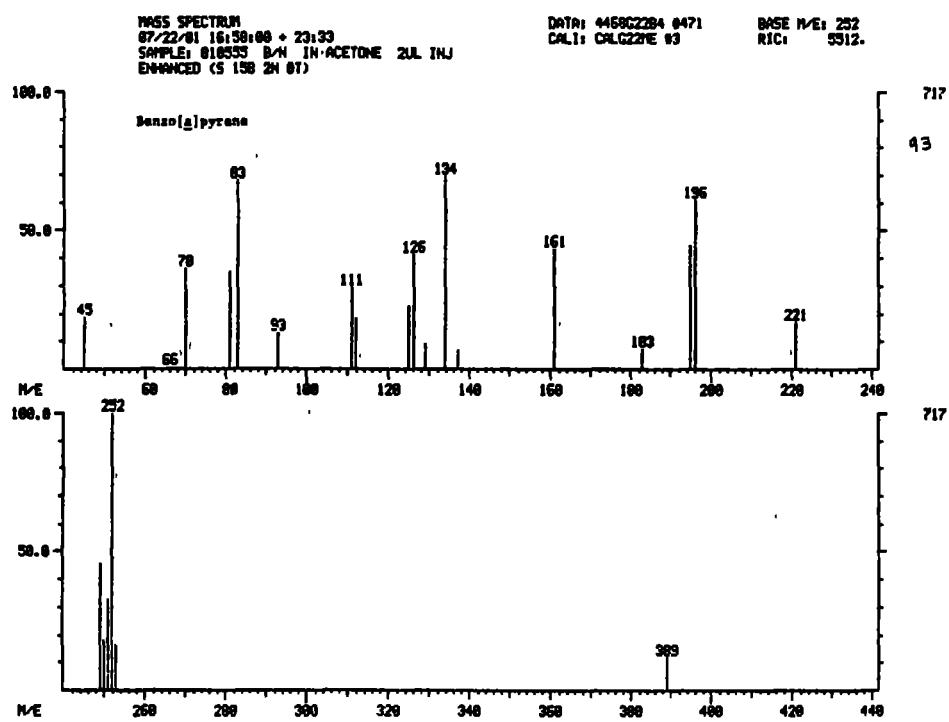


Figure 93. Mass spectrum of benzo[a]pyrene in sample 810555.

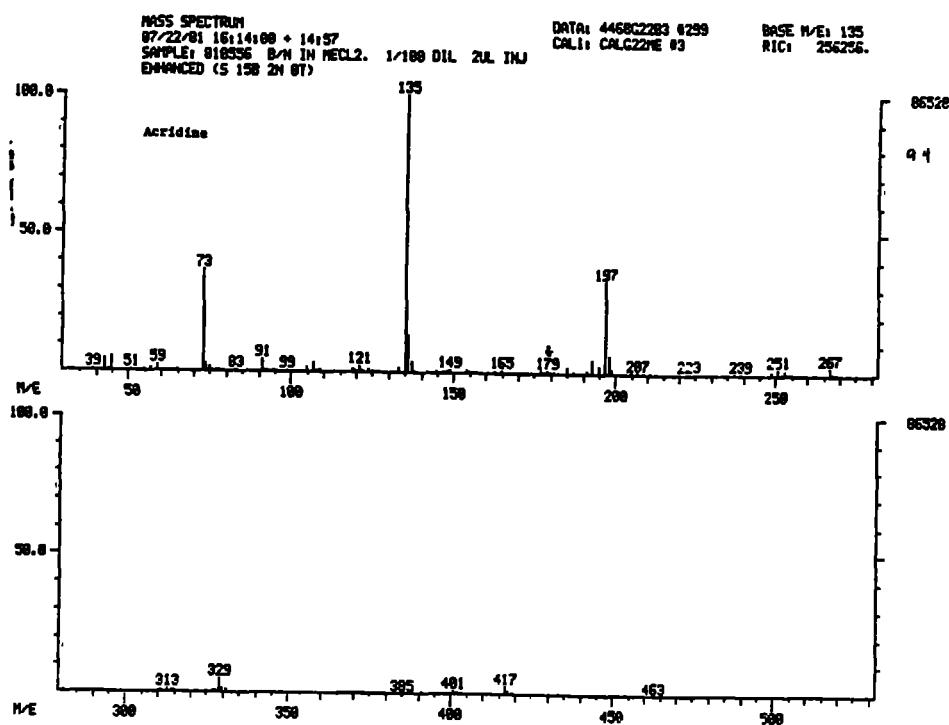


Figure 94. Mass spectrum of acridine in sample 810556.

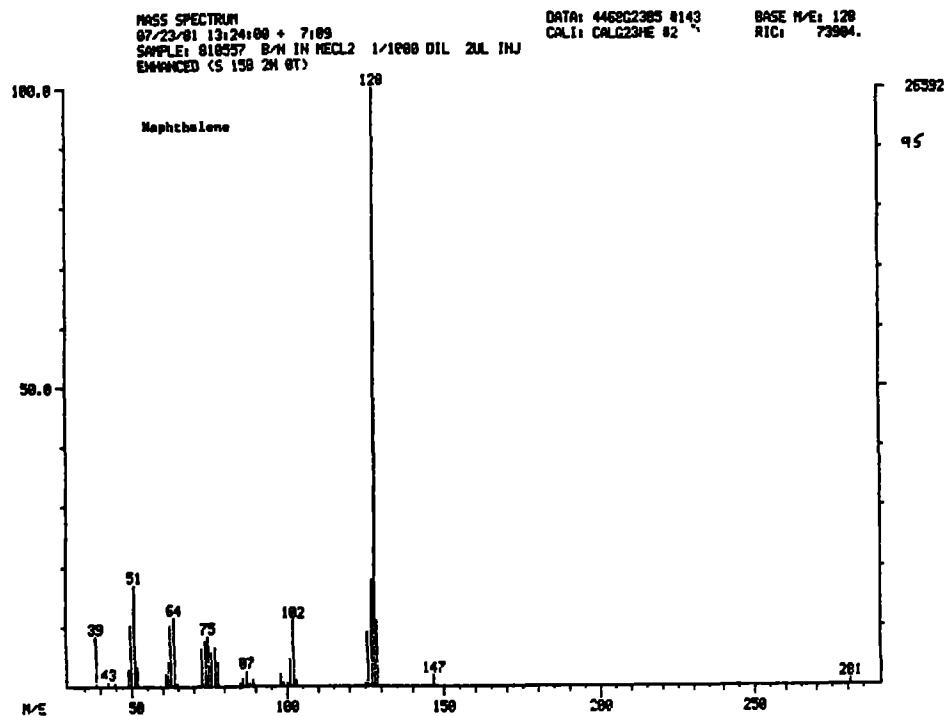


Figure 95. Mass spectrum of naphthalene in sample 810557.

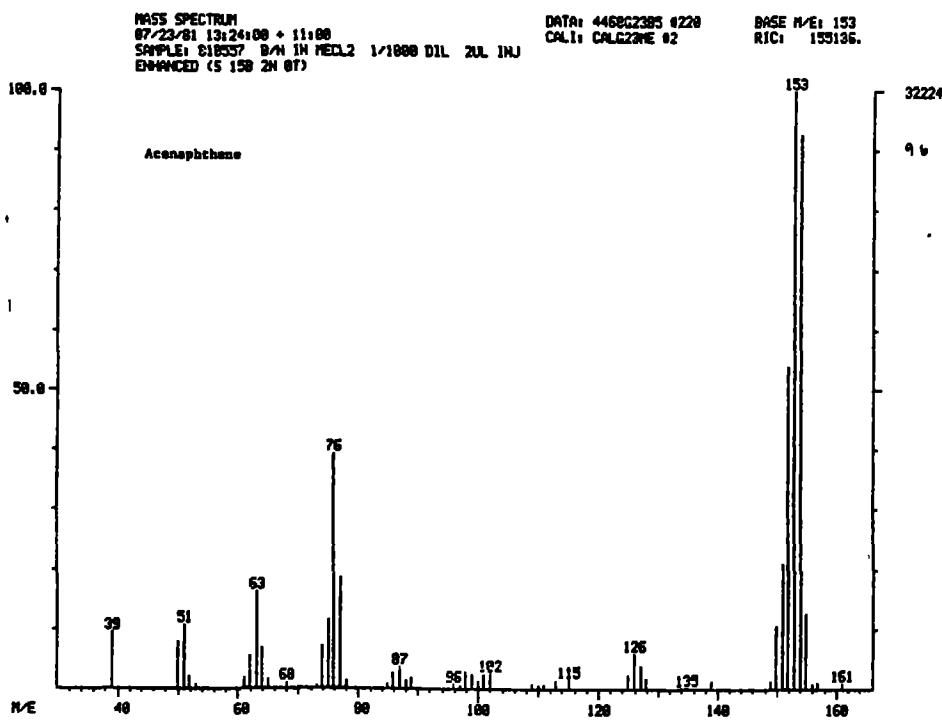


Figure 96. Mass spectrum of acenaphthene in sample 810557.

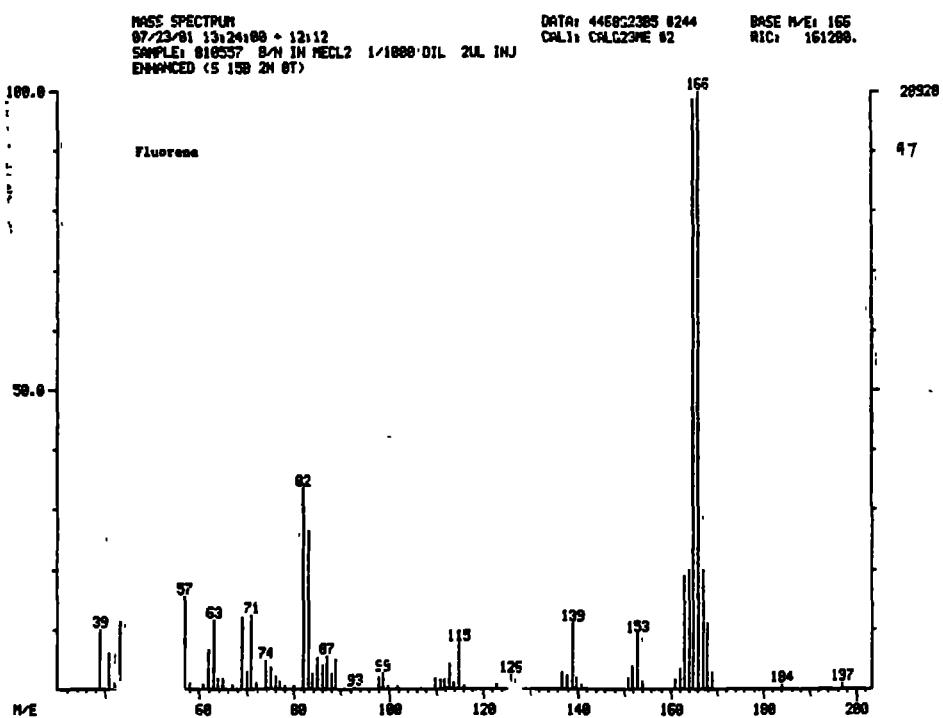


Figure 97. Mass spectrum of fluorene in sample 810557.

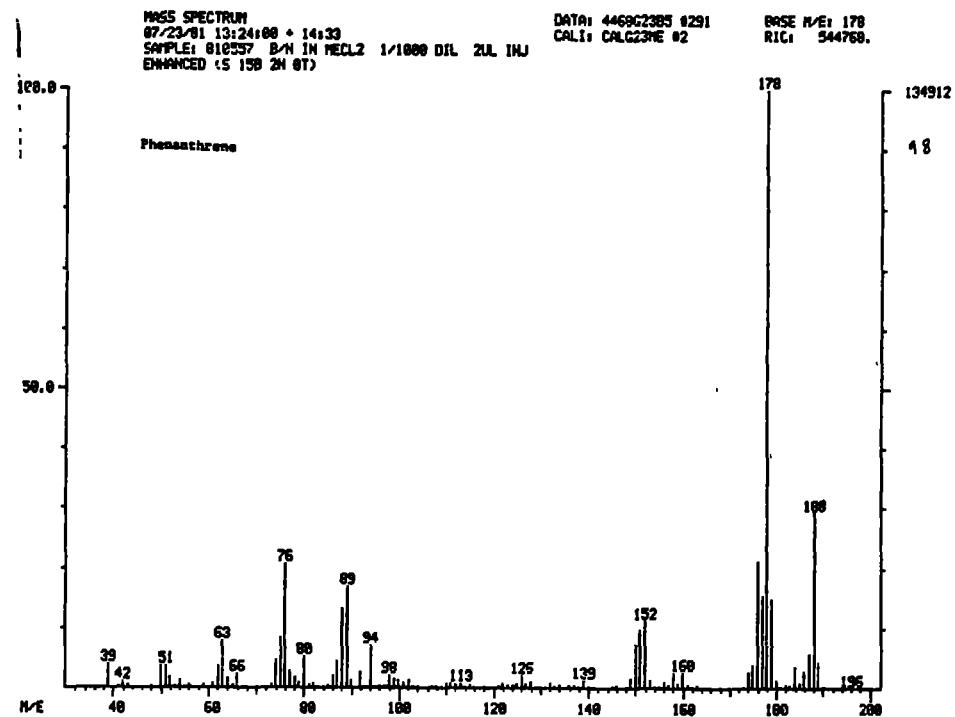


Figure 98. Mass spectrum of phenanthrene in sample 810557.

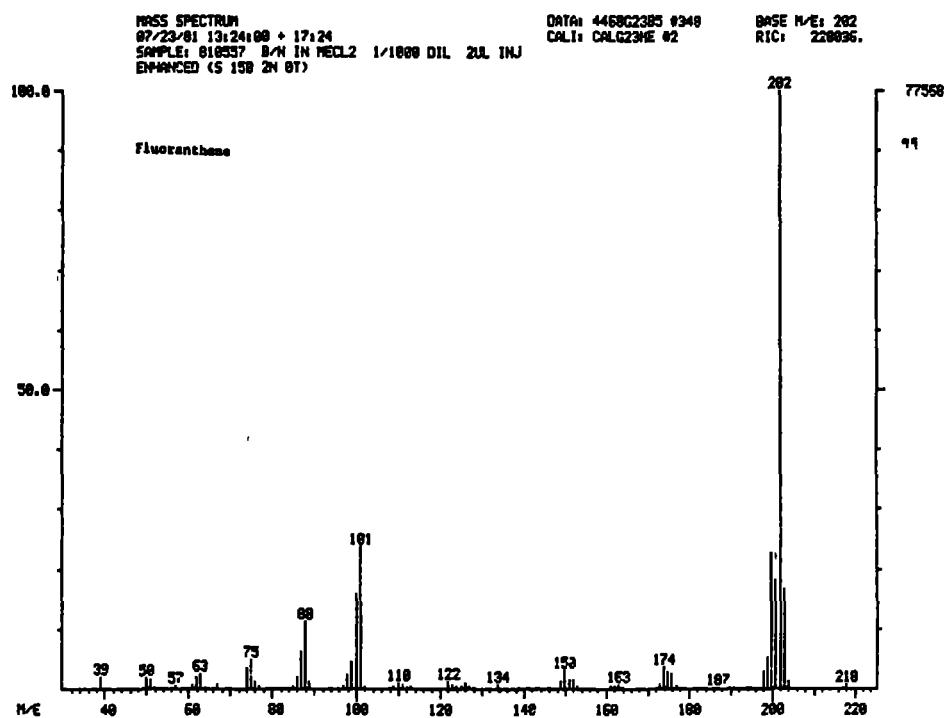


Figure 99. Mass spectrum of fluoranthene in sample 810557.

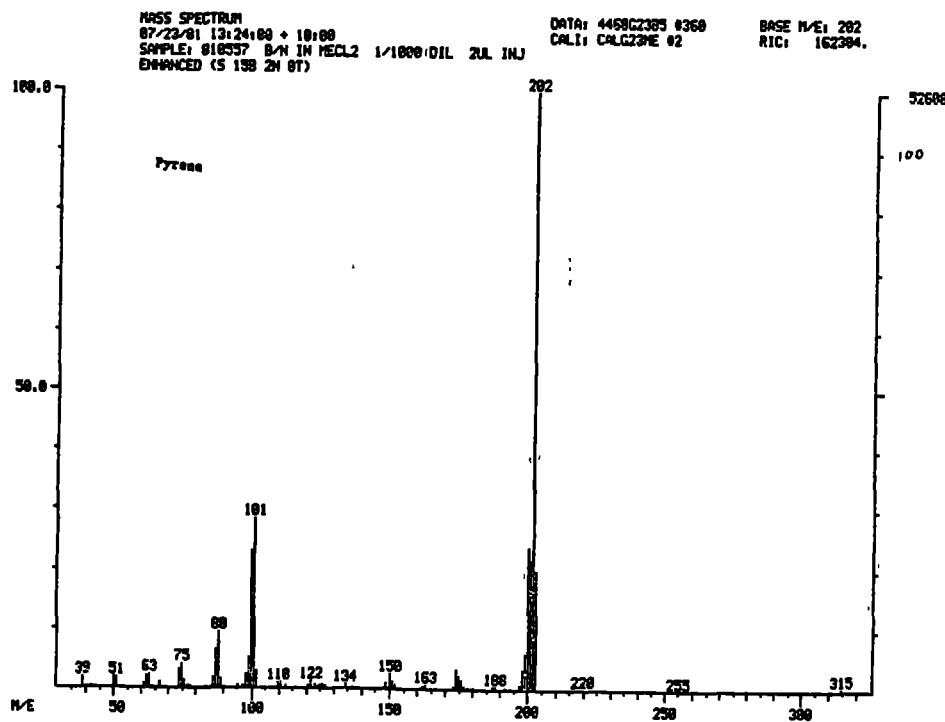


Figure 100. Mass spectrum of pyrene in sample 810557.

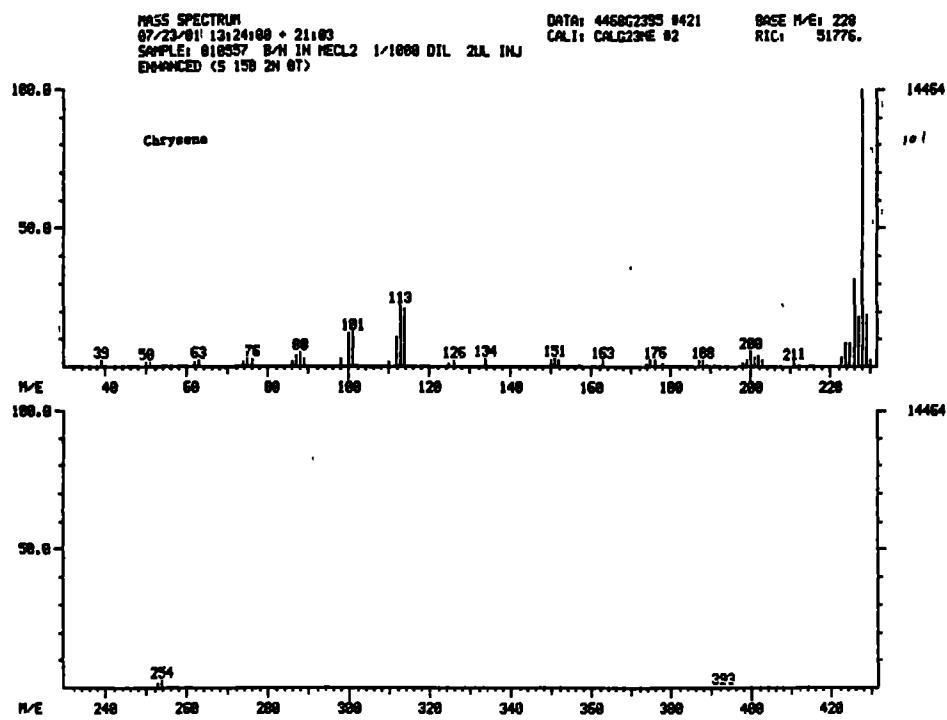


Figure 101. Mass spectrum of chrysene in sample 810557.

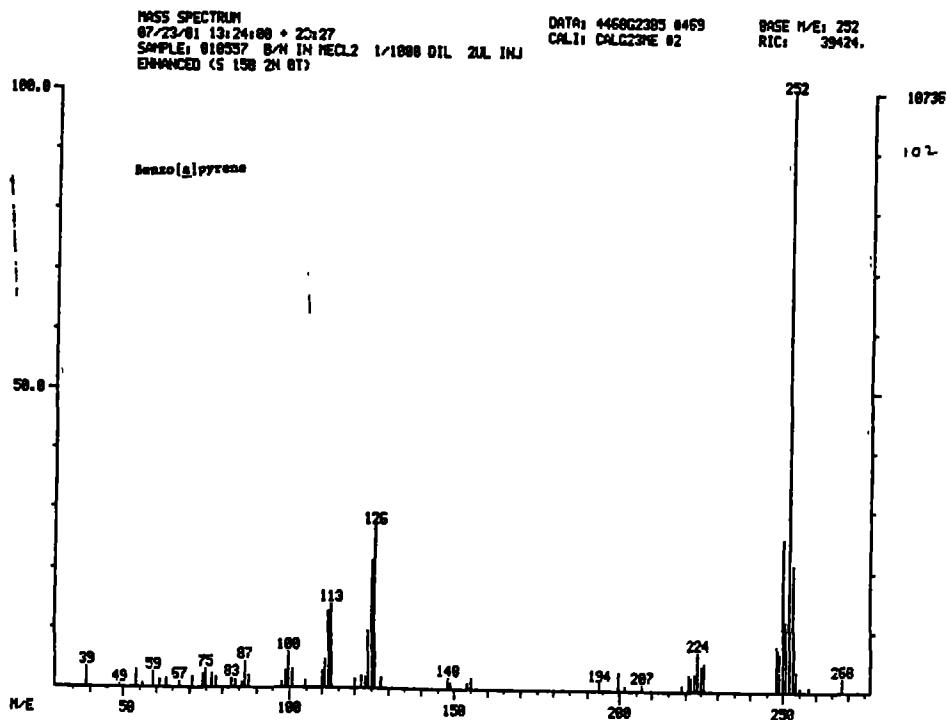


Figure 102. Mass spectrum of benzo[a]pyrene in sample 810557.

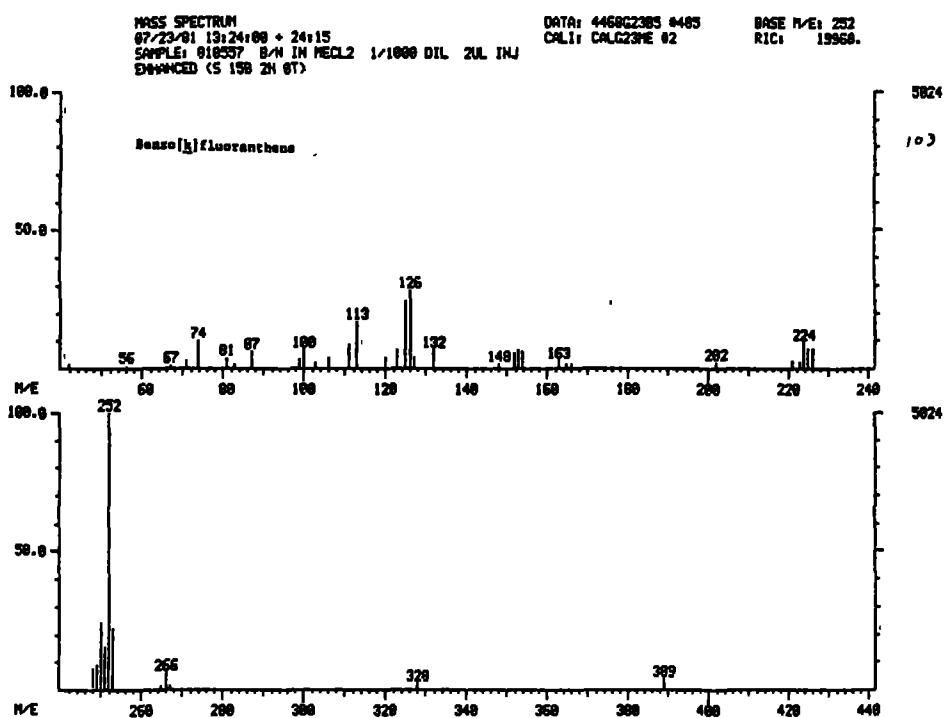


Figure 103. Mass spectrum of benzo[k]fluoranthene in sample 810557.

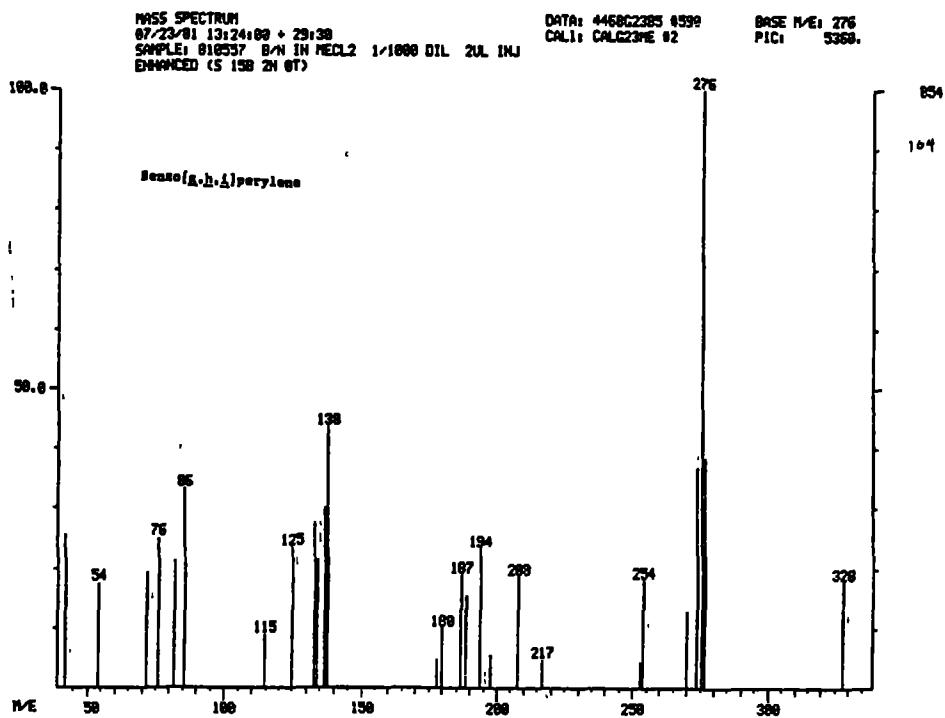


Figure 104. Mass spectrum of benzo[g,h,i]perylene in sample 810557.

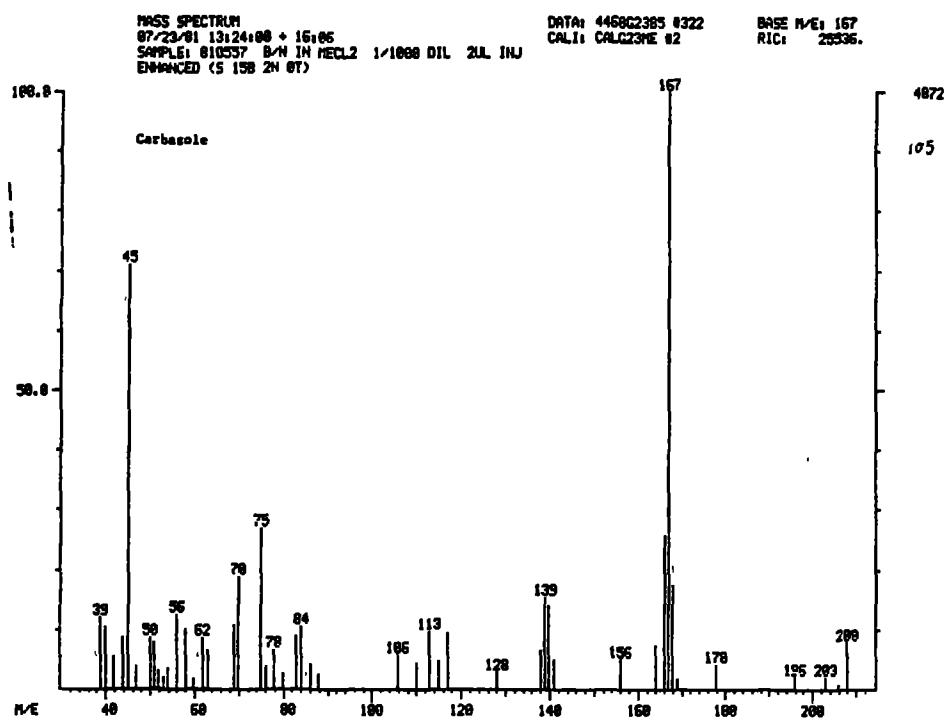


Figure 105. Mass spectrum of carbazole in sample 810557.

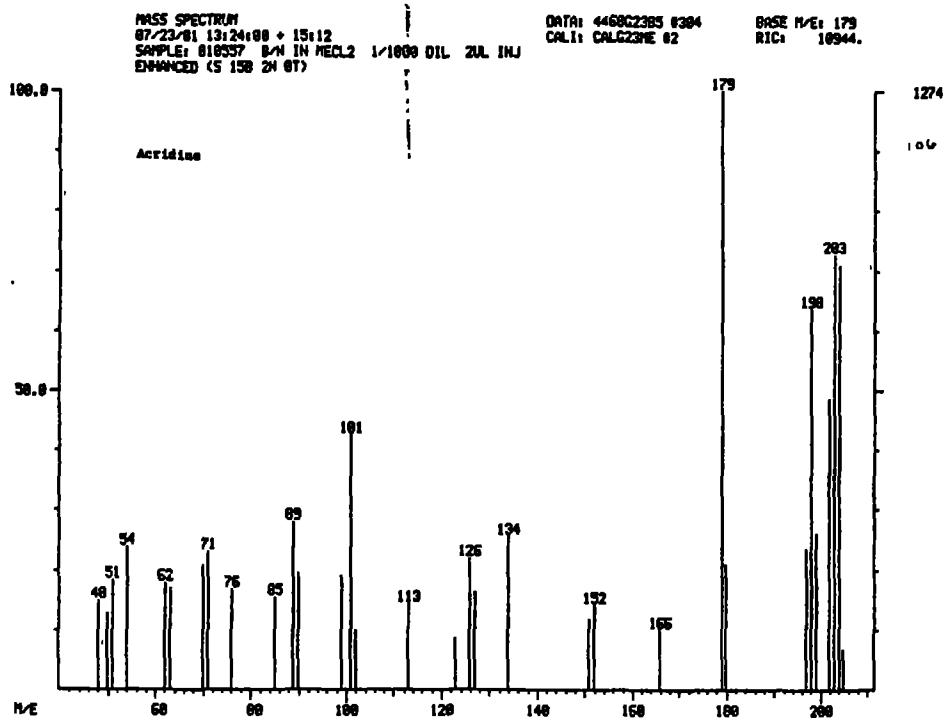


Figure 106. Mass spectrum of acridine in sample 810557.

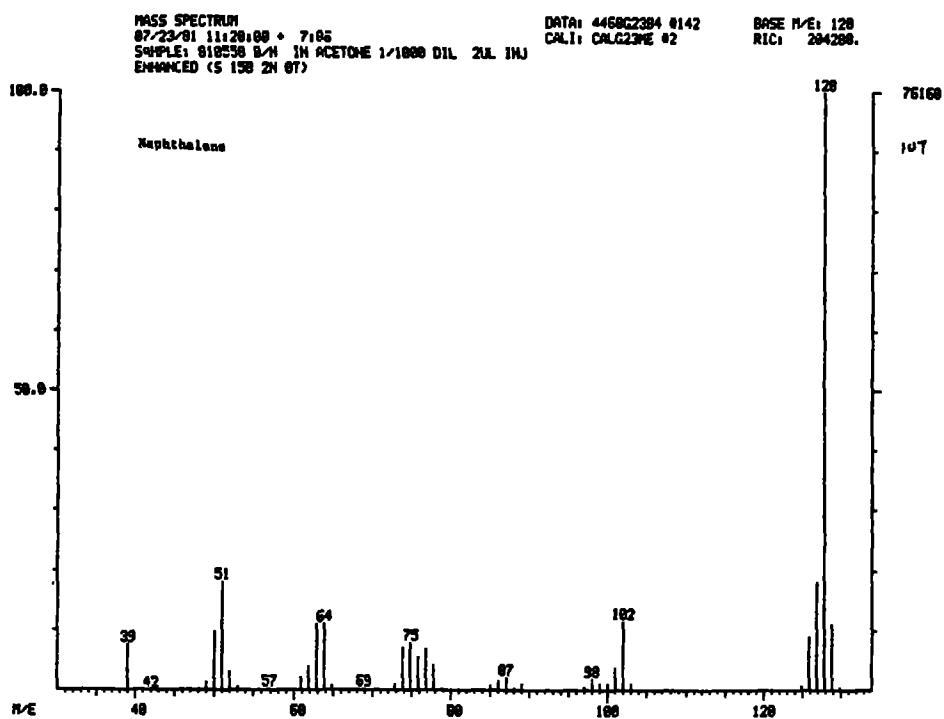


Figure 107. Mass spectrum of naphthalene in sample 810558.

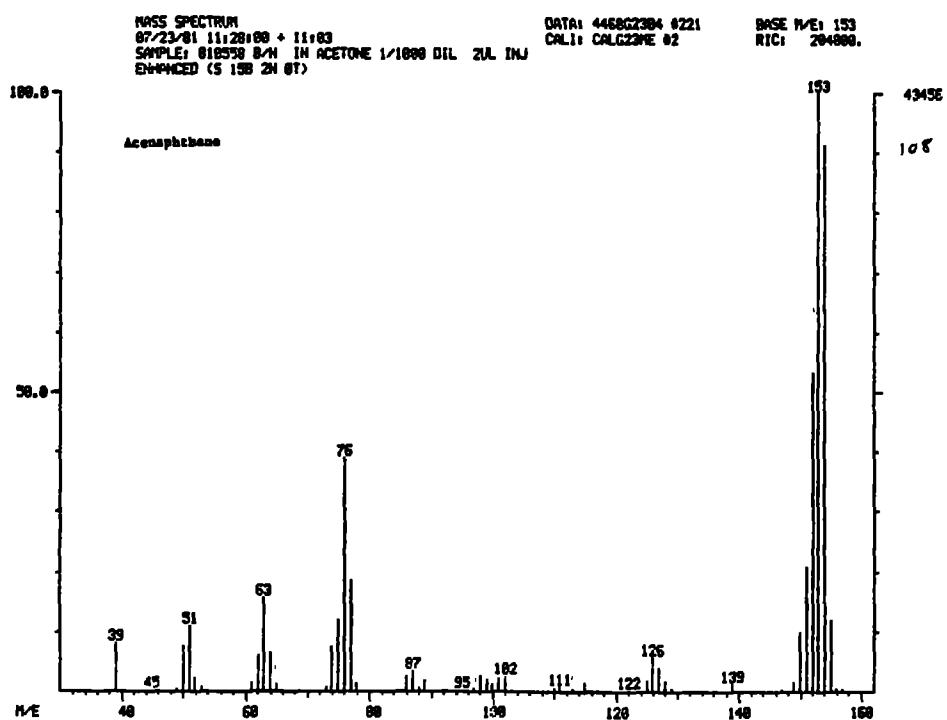


Figure 108. Mass spectrum of acenaphthene in sample 810558.

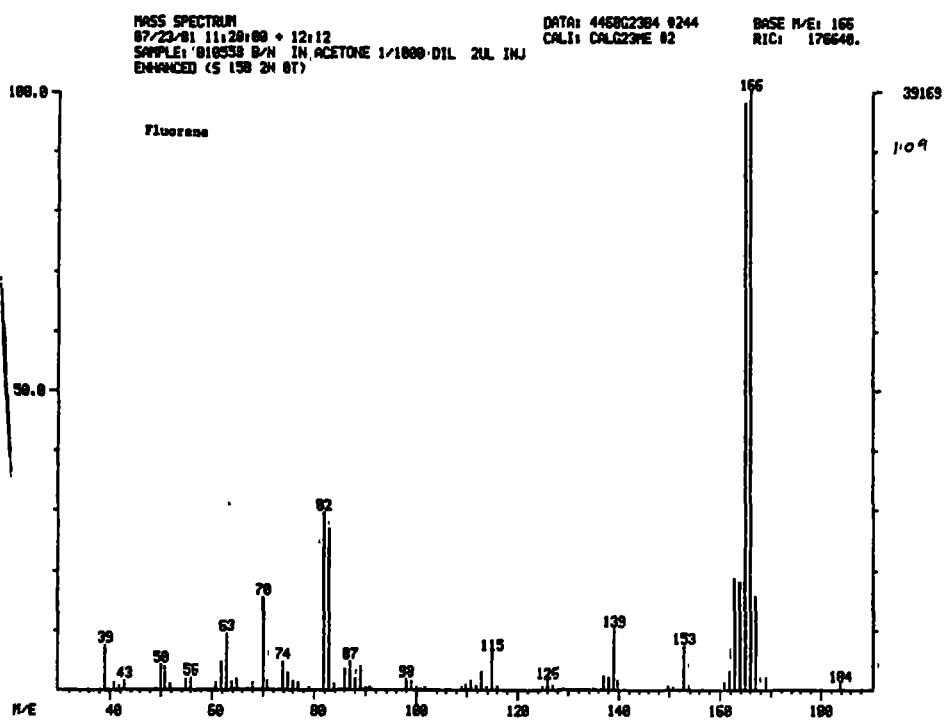


Figure 109. Mass spectrum of fluorene in sample 810558.

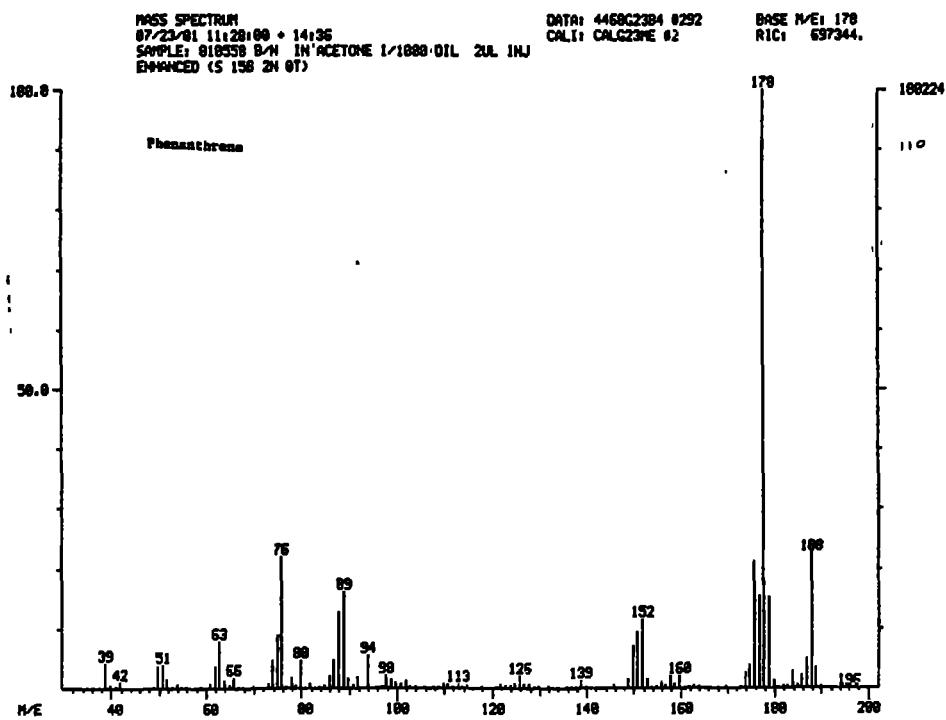


Figure 110. Mass spectrum of phenanthrene in sample 810558.

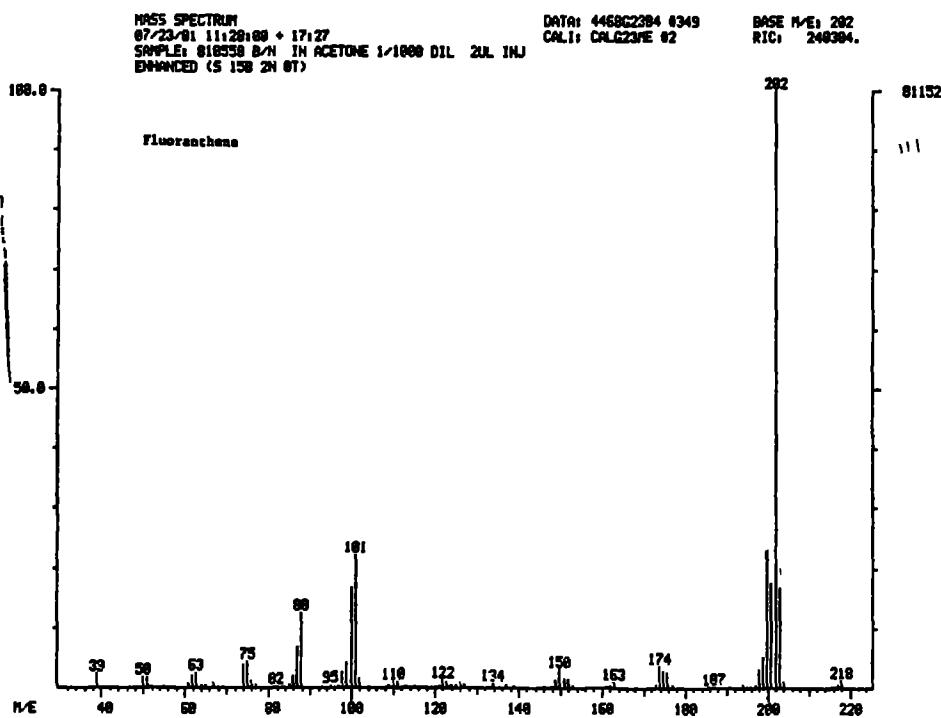


Figure 111. Mass spectrum of fluoranthene in sample 810558.

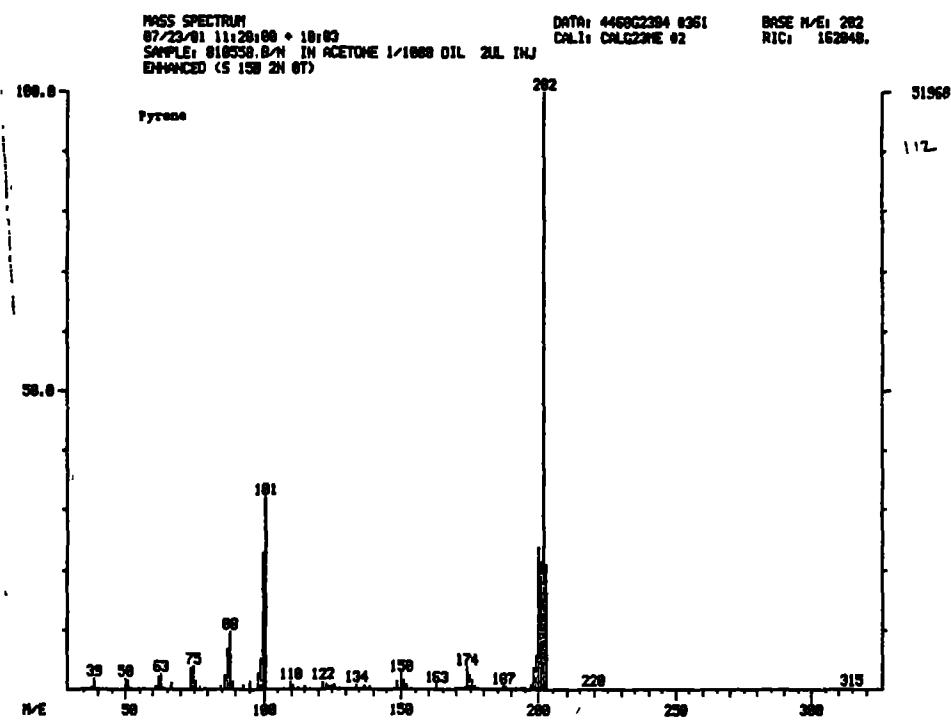


Figure 112. Mass spectrum of pyrene in sample 810558.

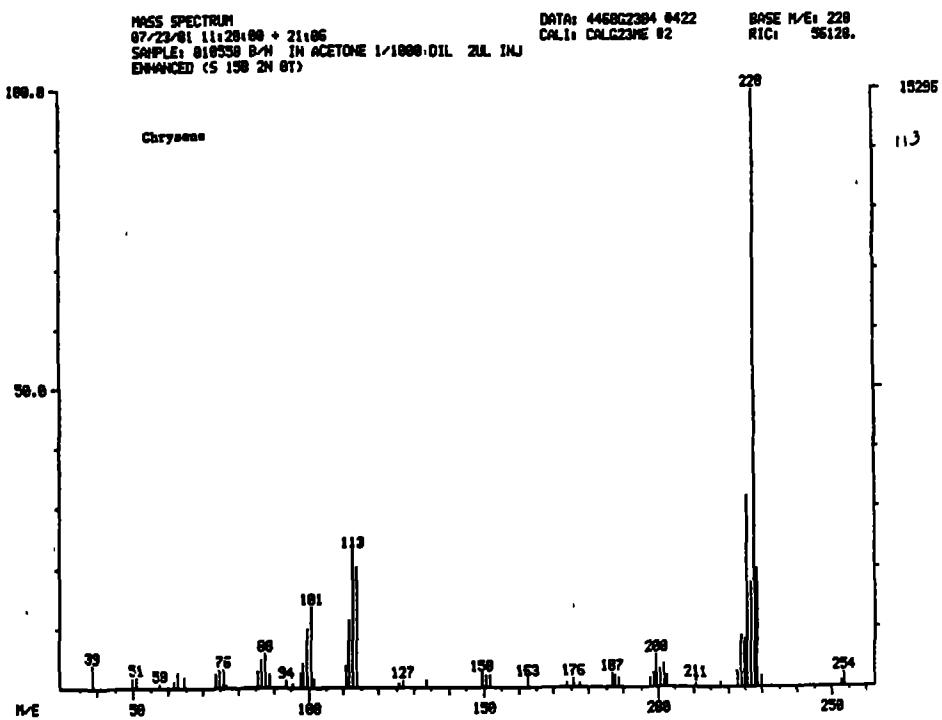


Figure 113. Mass spectrum of chrysens in sample 810558.

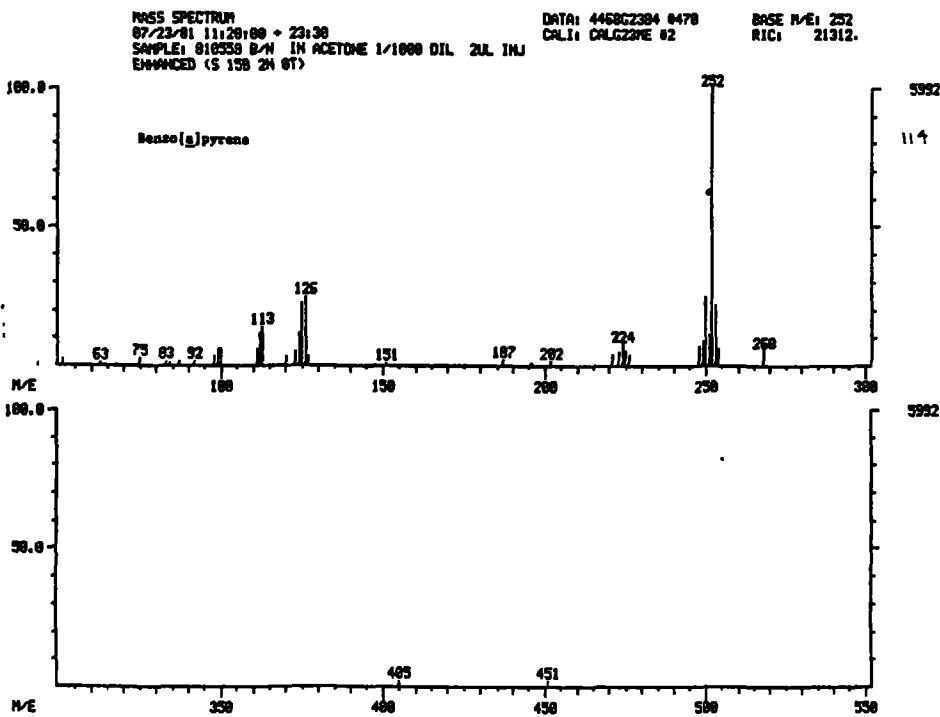


Figure 114. Mass spectrum of benzo[a]pyrene in sample 810558.

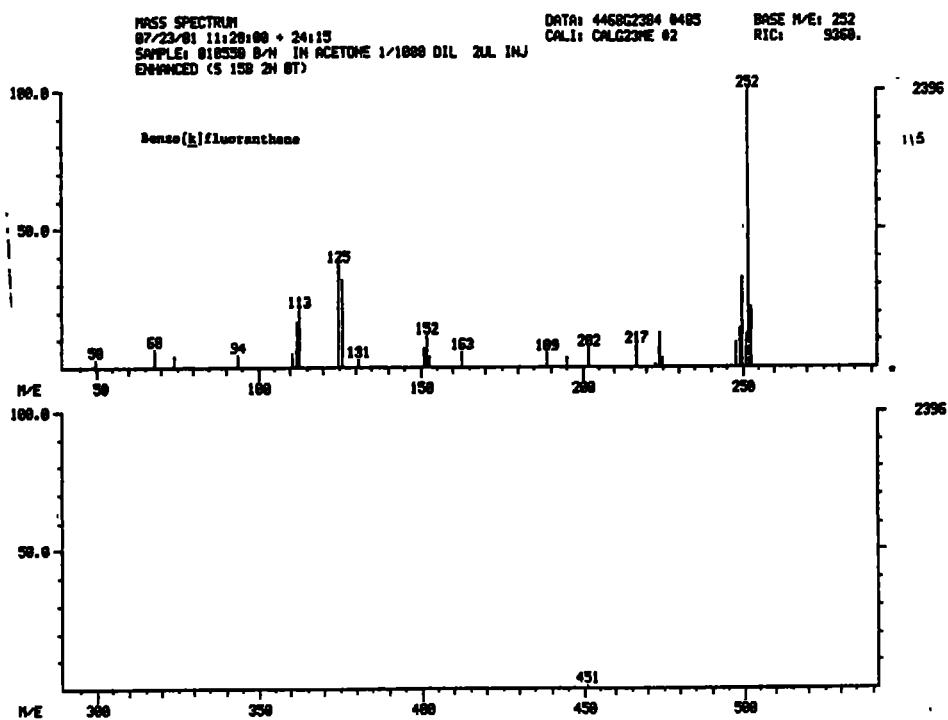


Figure 115. Mass spectrum of benzo[k]fluoranthene in sample 810558.

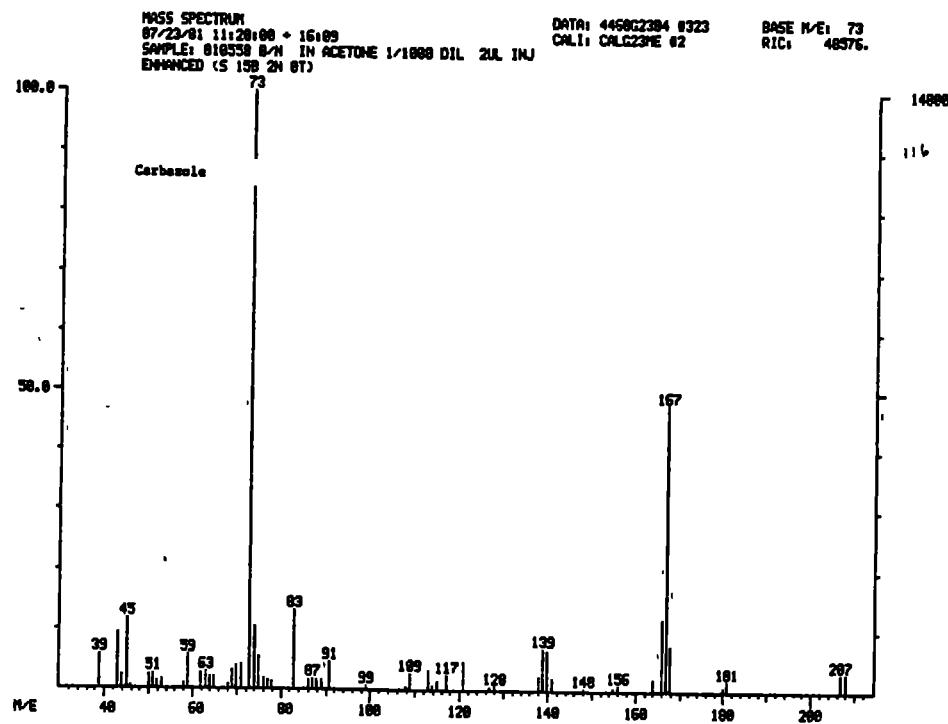


Figure 116. Mass spectrum of carbazole in sample 810558.

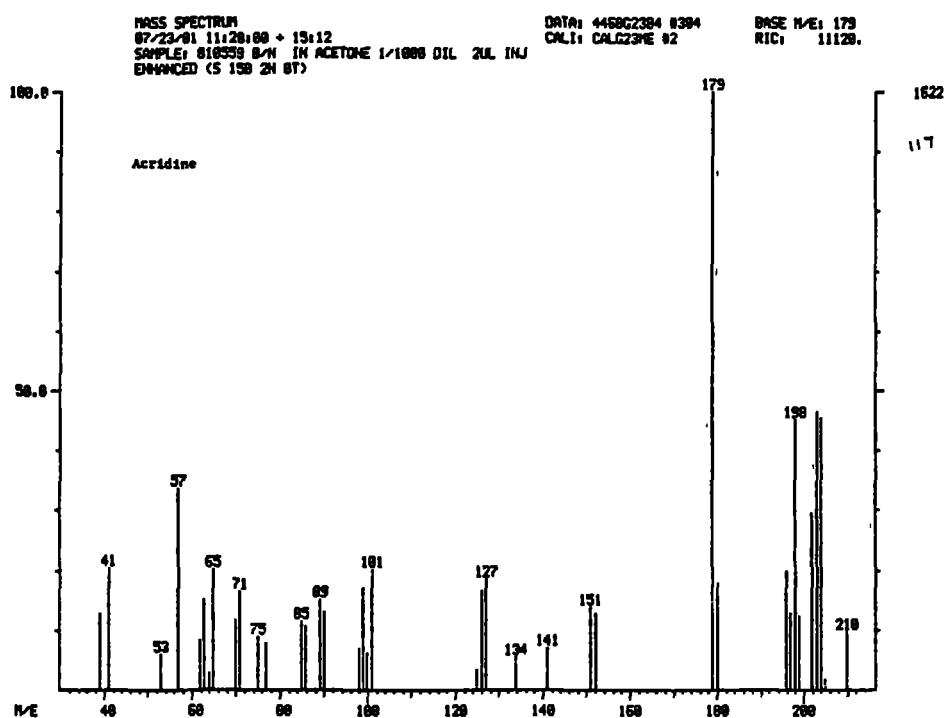


Figure 117. Mass spectrum of acridine in sample 810558.

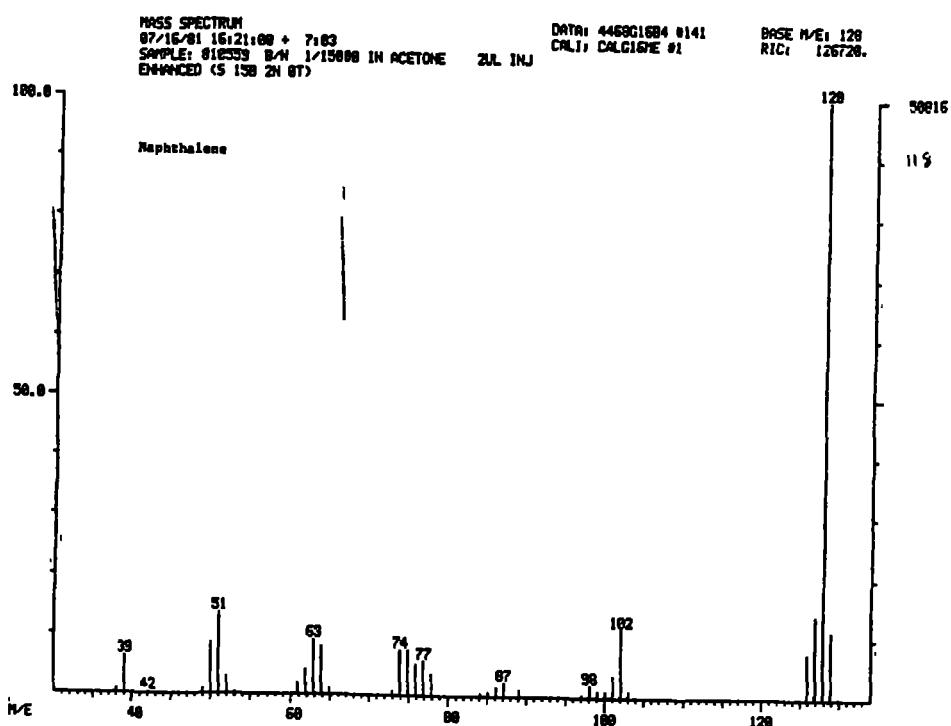


Figure 118. Mass spectrum of naphthalene in sample 810559.

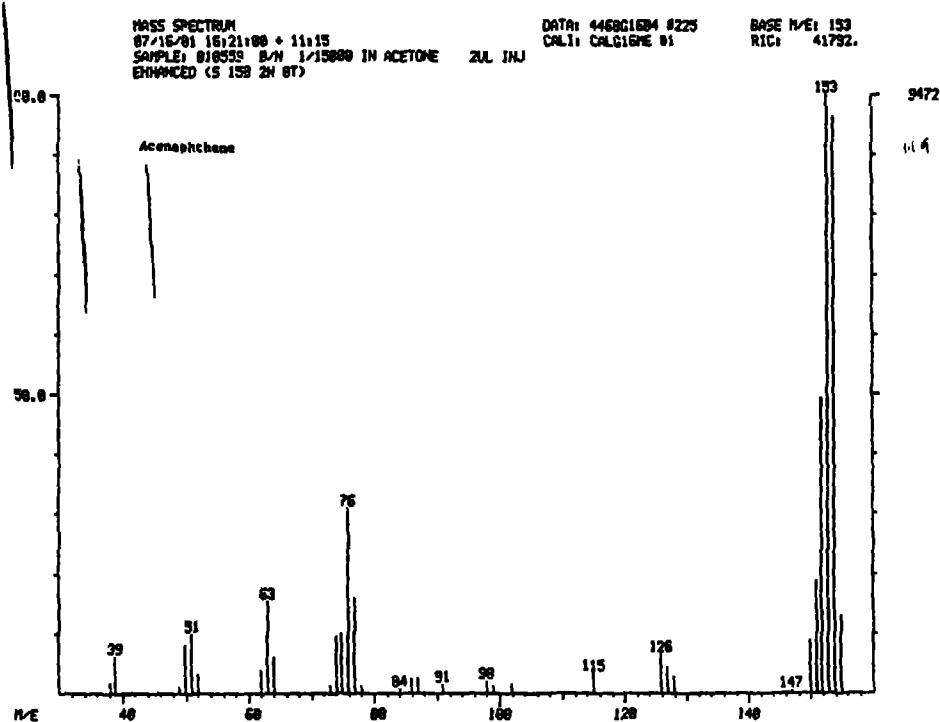


Figure 119. Mass spectrum of acenaphthene in sample 810559.

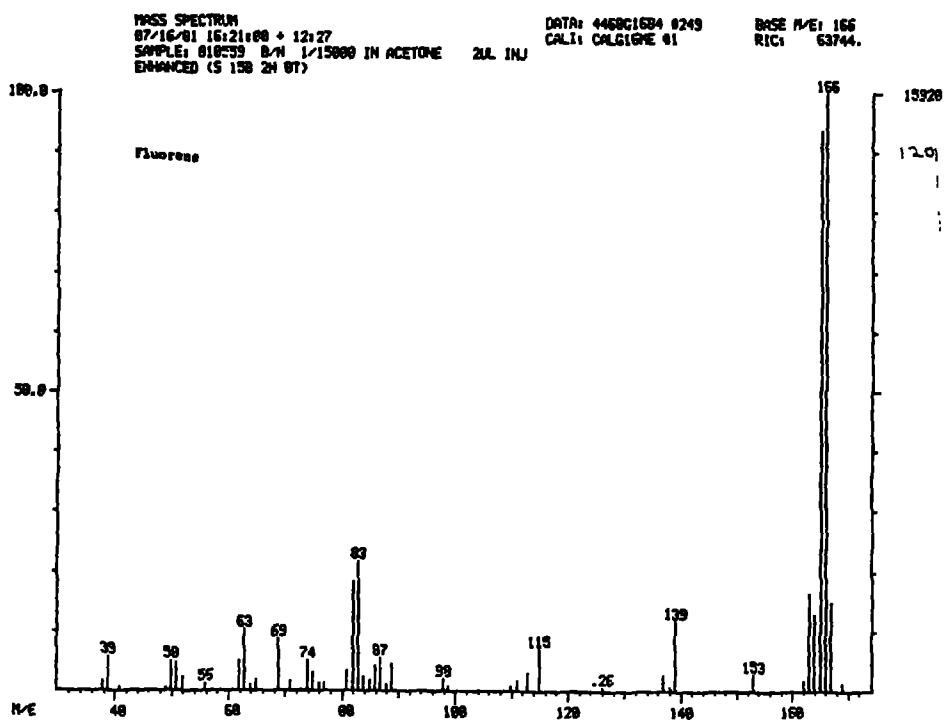


Figure 120. Mass spectrum of fluorene in sample 810559.

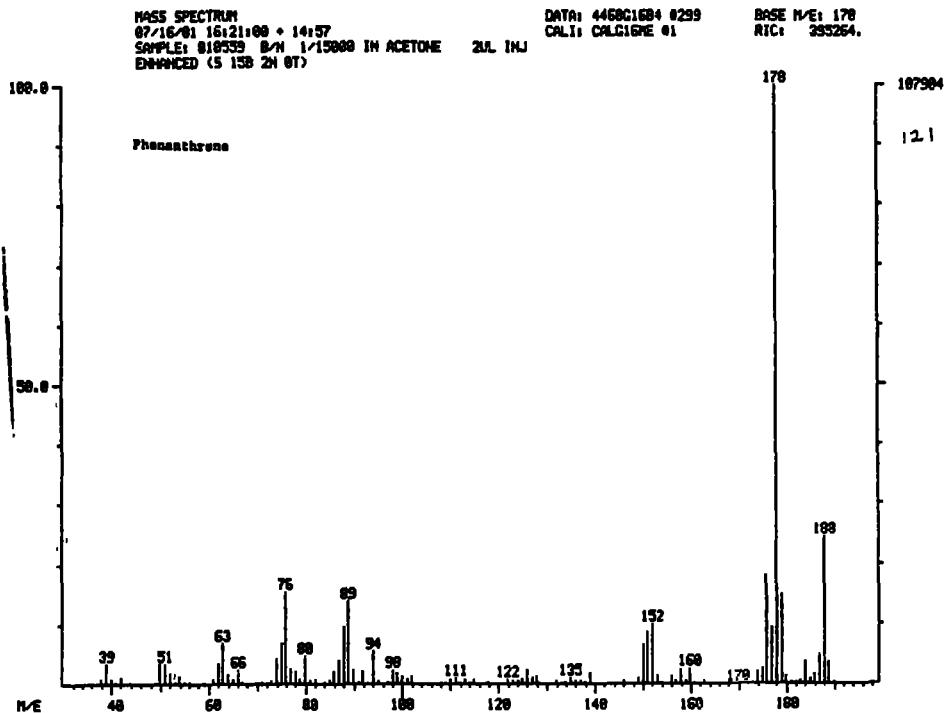


Figure 121. Mass spectrum of phenanthrene in sample 810559.

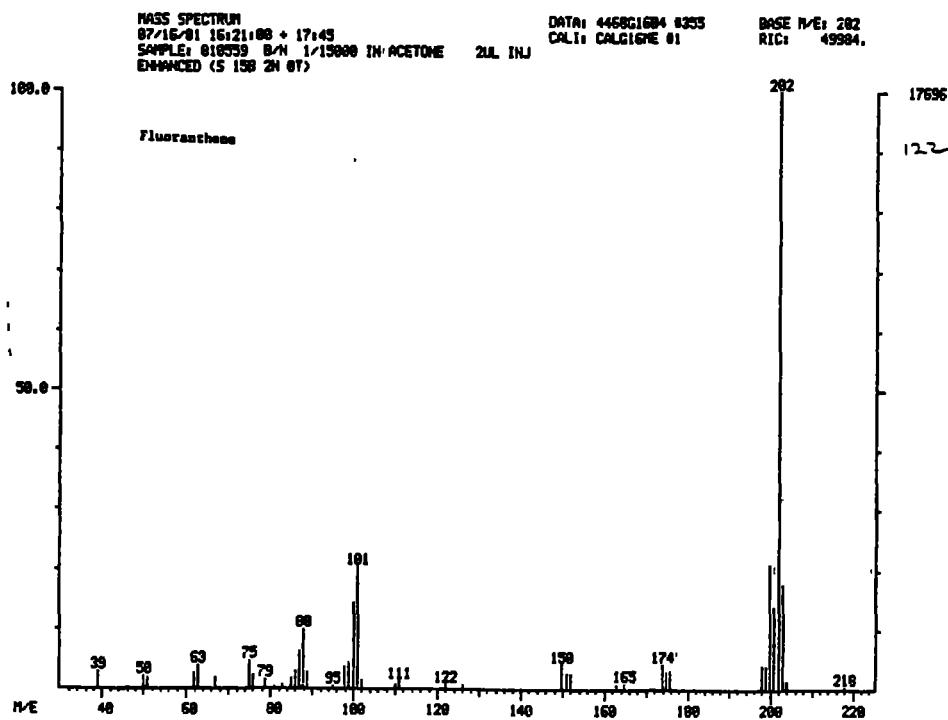


Figure 122. Mass spectrum of fluoranthene in sample 810559.

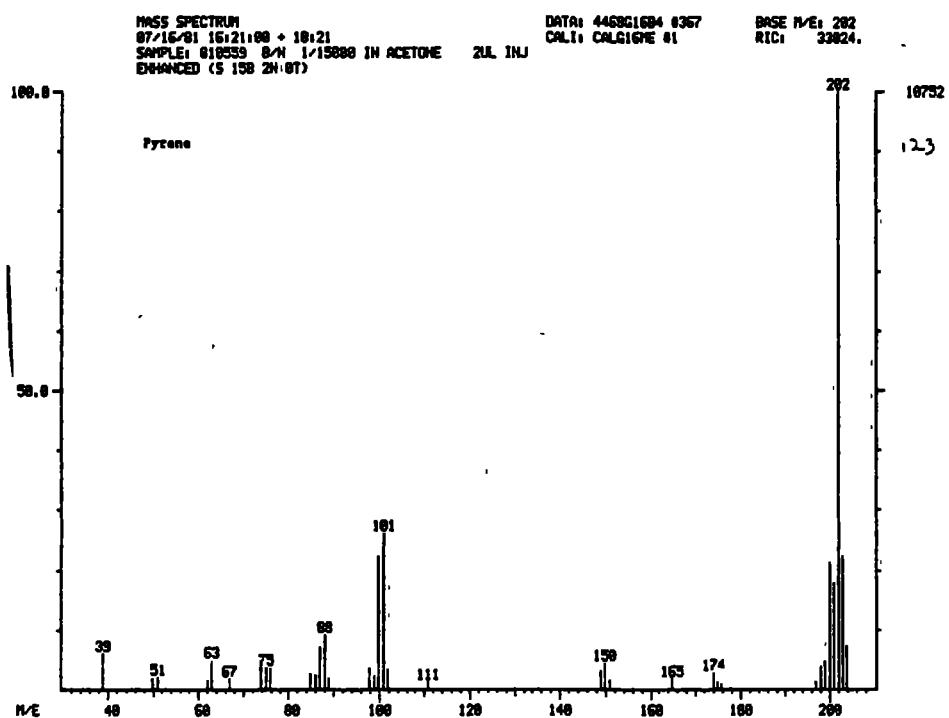


Figure 123. Mass spectrum of pyrene in sample 810559.

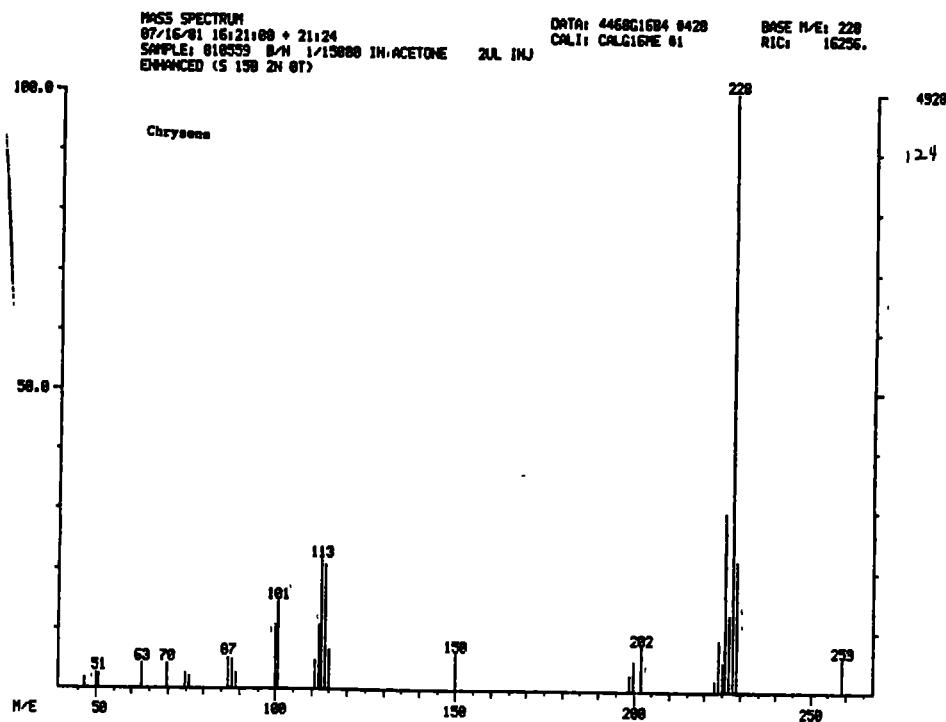


Figure 124. Mass spectrum of chrysene in sample 810559.

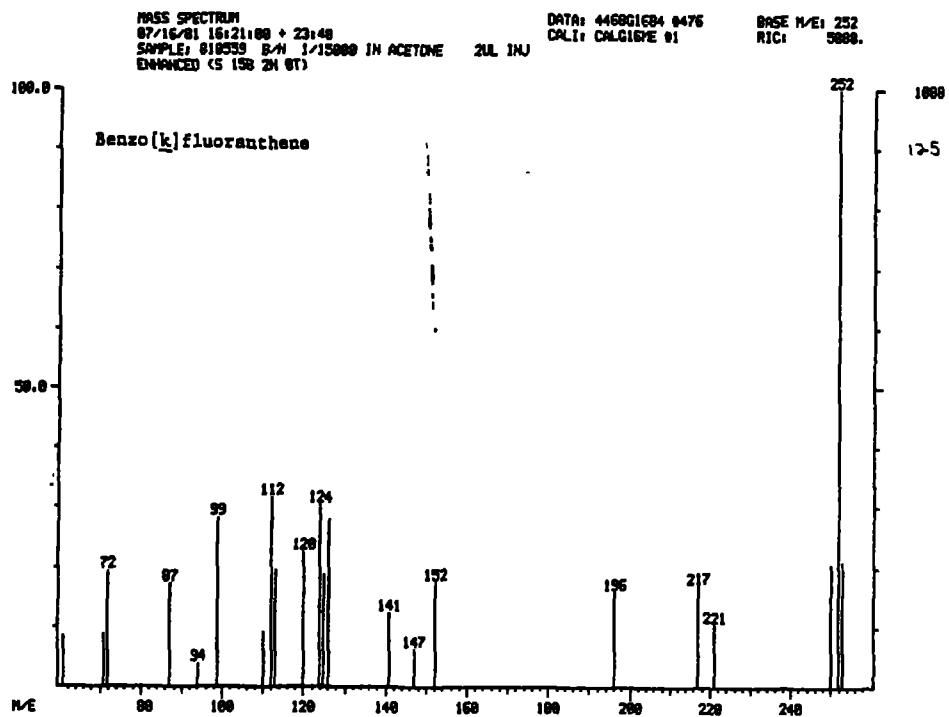


Figure 125. Mass spectrum of benzo[k]fluoranthene in sample 810559.

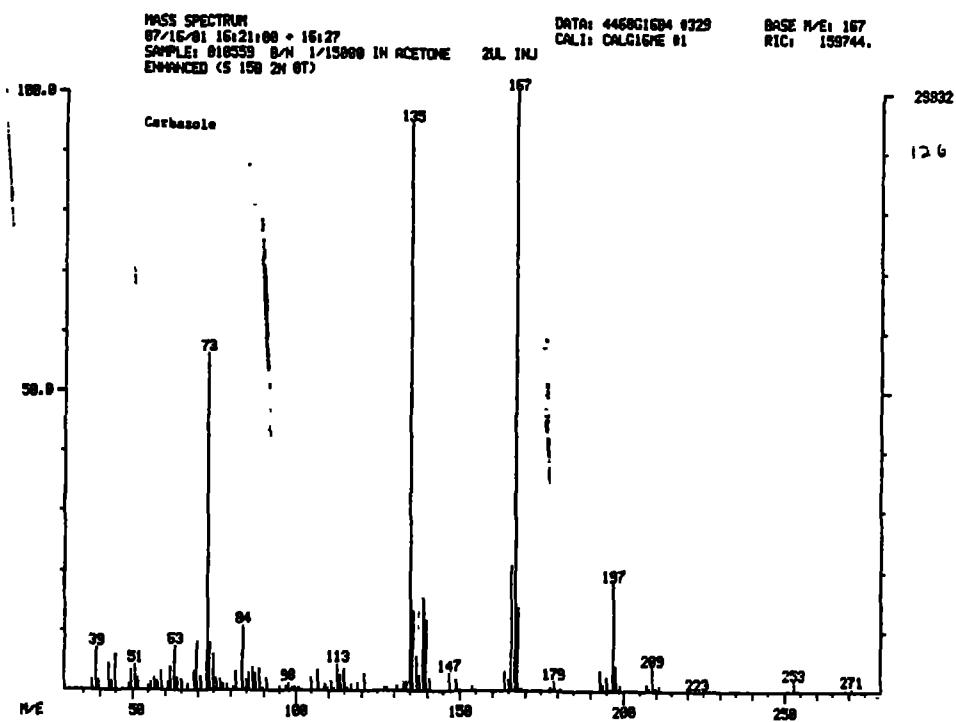


Figure 126. Mass spectrum of carbazole in sample 810559.

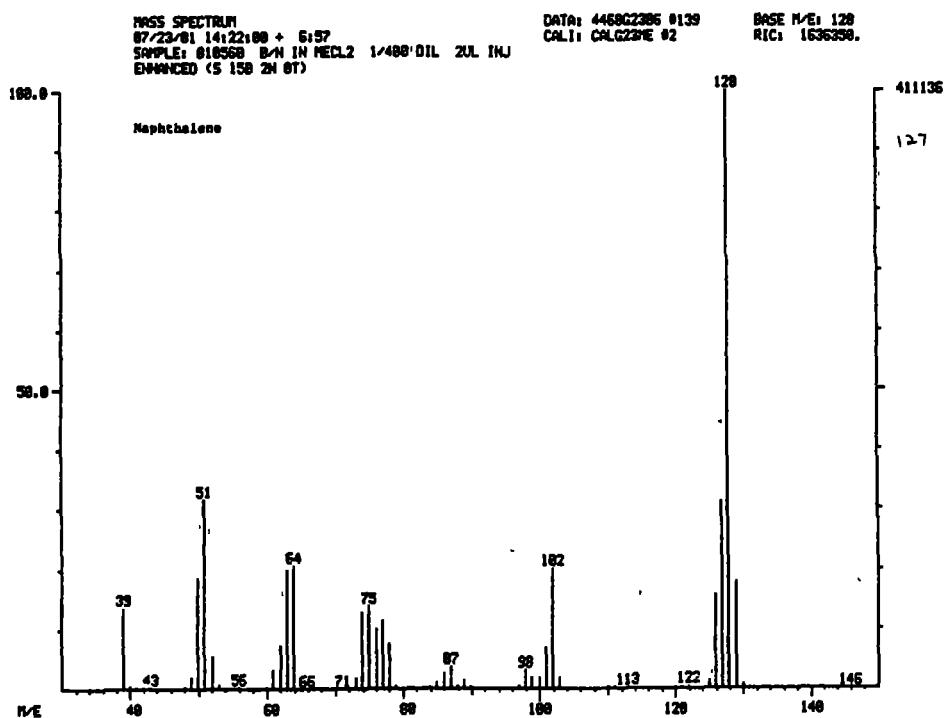


Figure 127. Mass spectrum of naphthalene in sample 810560.

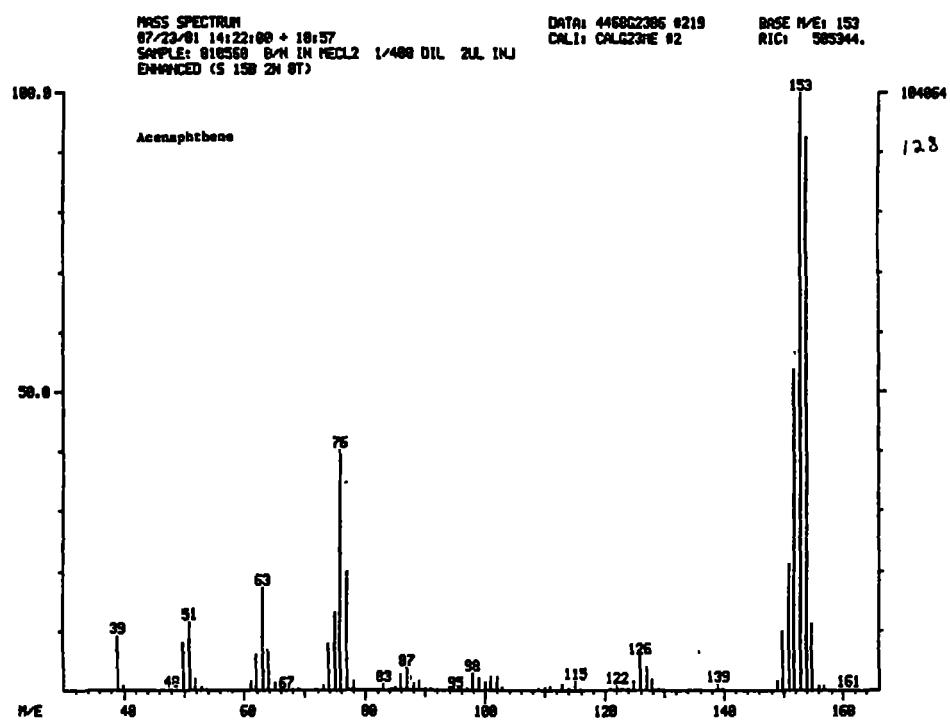


Figure 128. Mass spectrum of acenaphthene in sample 810560.

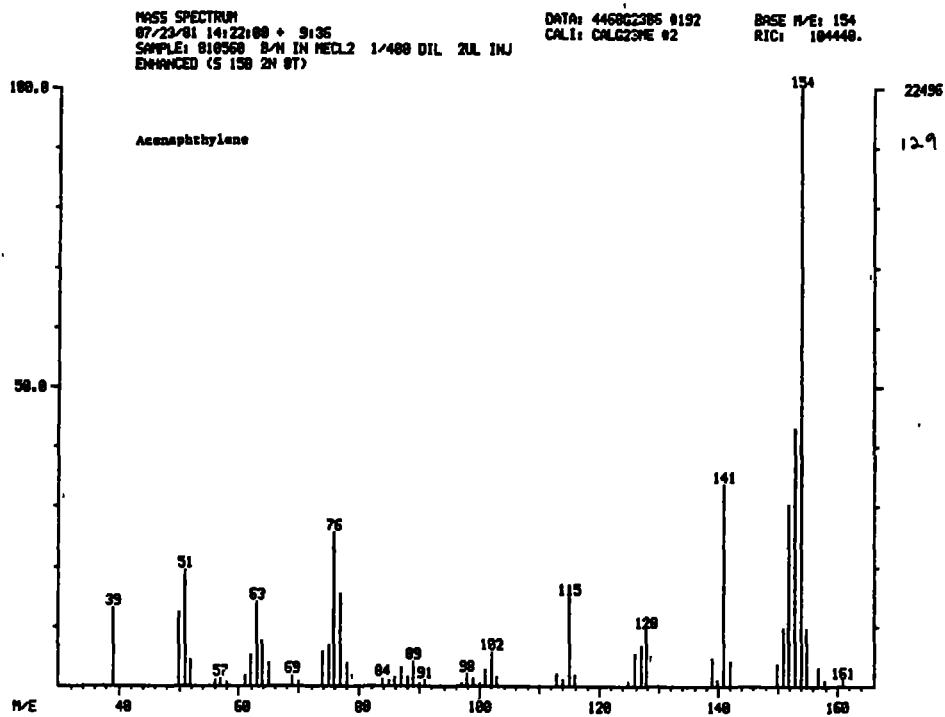


Figure 129. Mass spectrum of acenaphthylene in sample 810560.

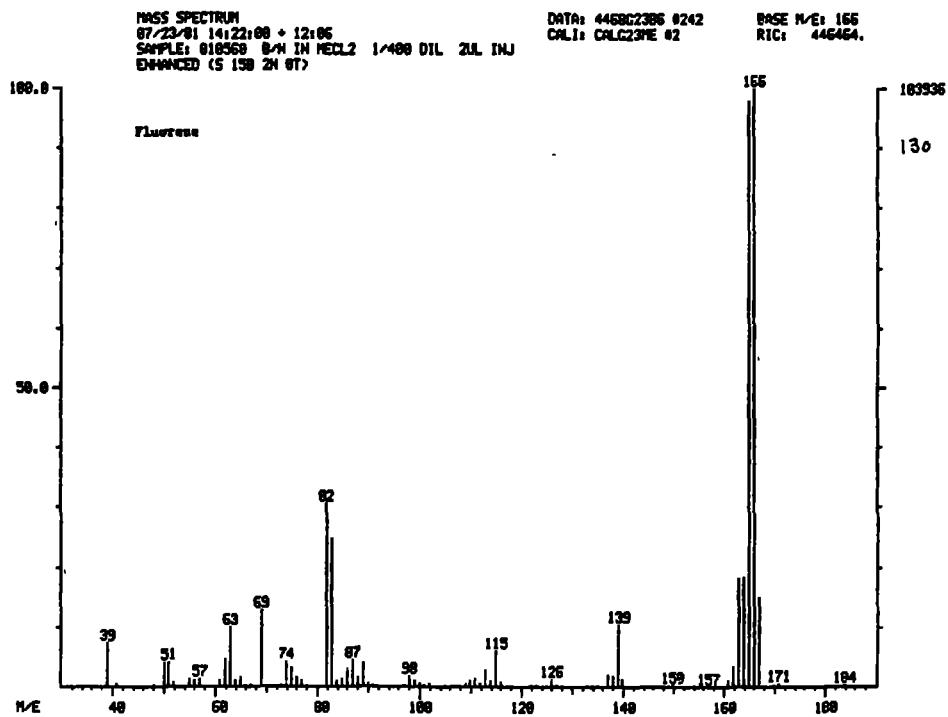


Figure 130. Mass spectrum of fluorene in sample 810560.

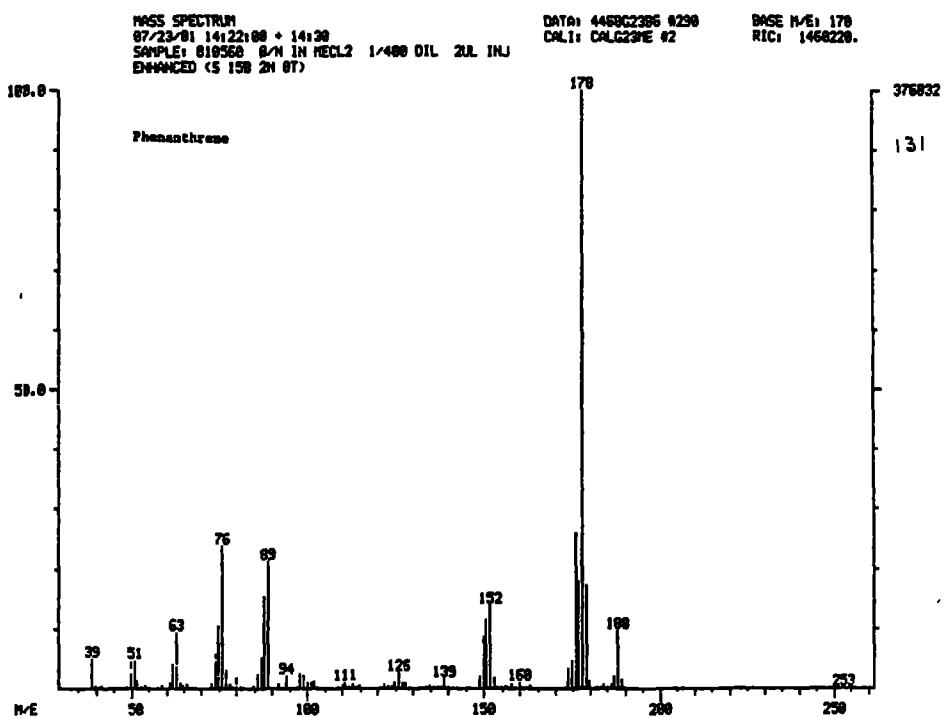


Figure 131. Mass spectrum of phenanthrene in sample 810560.

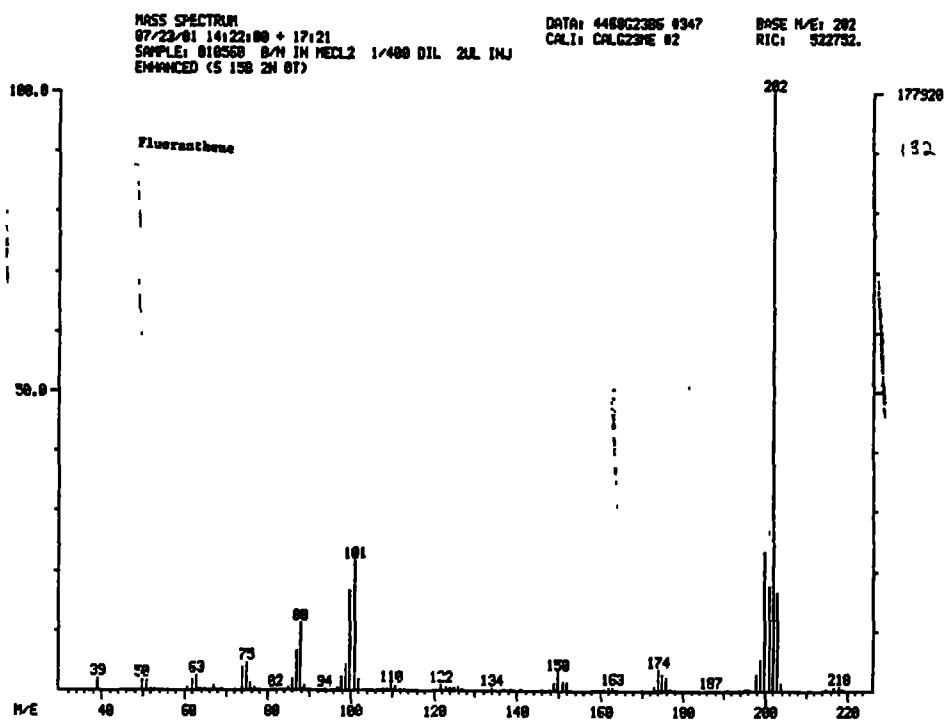


Figure 132. Mass spectrum of fluoranthene in sample 810560.

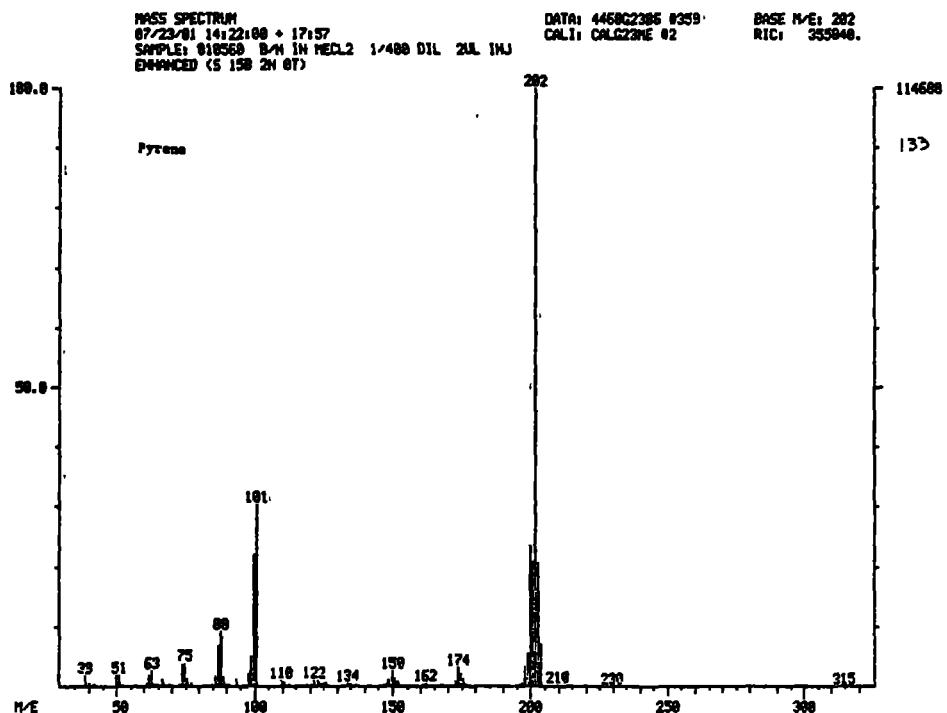


Figure 133. Mass spectrum of pyrene in sample 810560.

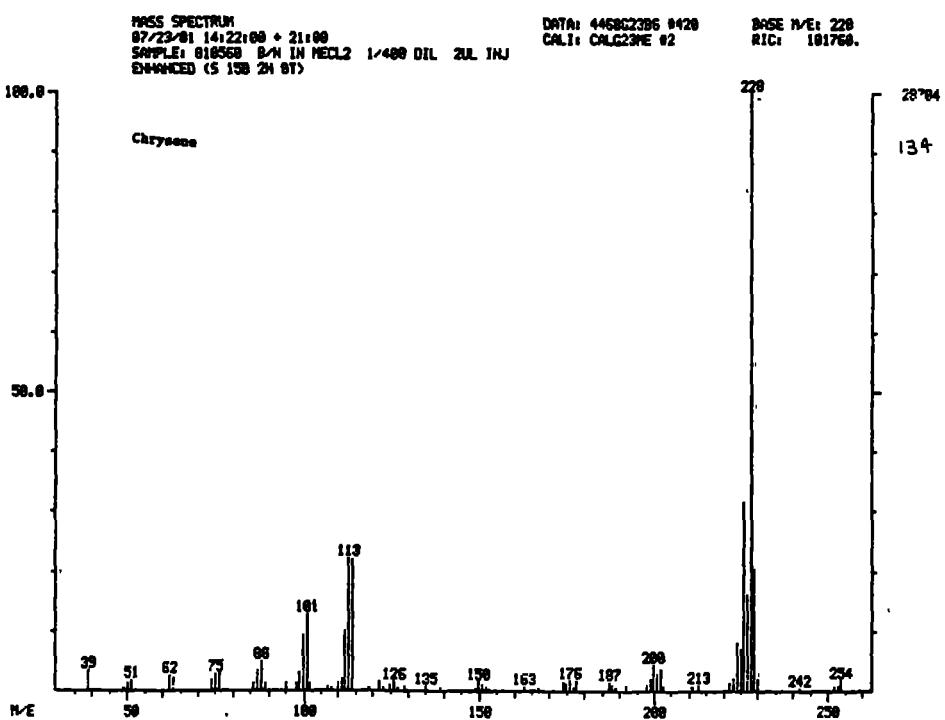


Figure 134. Mass spectrum of chrysene in sample 810560.

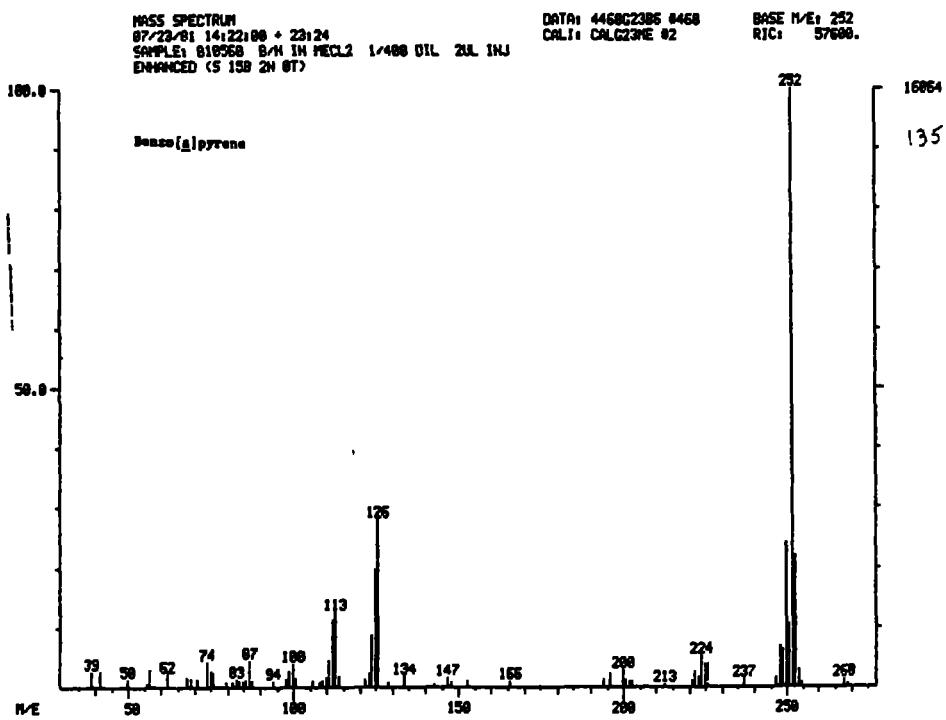


Figure 135. Mass spectrum of benzo[a]pyrene in sample 810560.

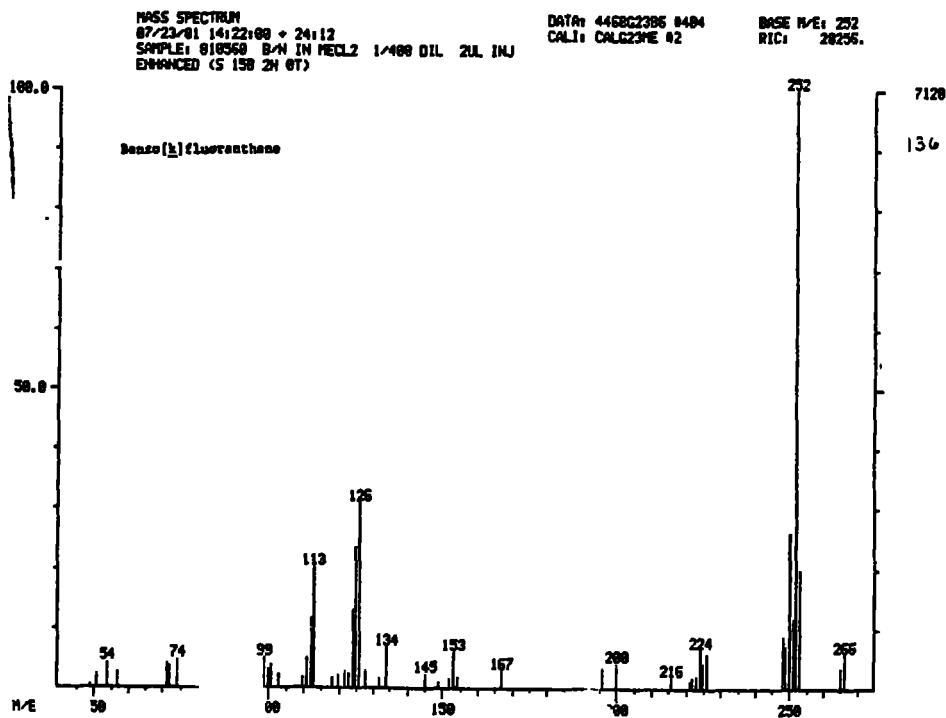


Figure 136. Mass spectrum of benzo[k]fluoranthene in sample 810560.

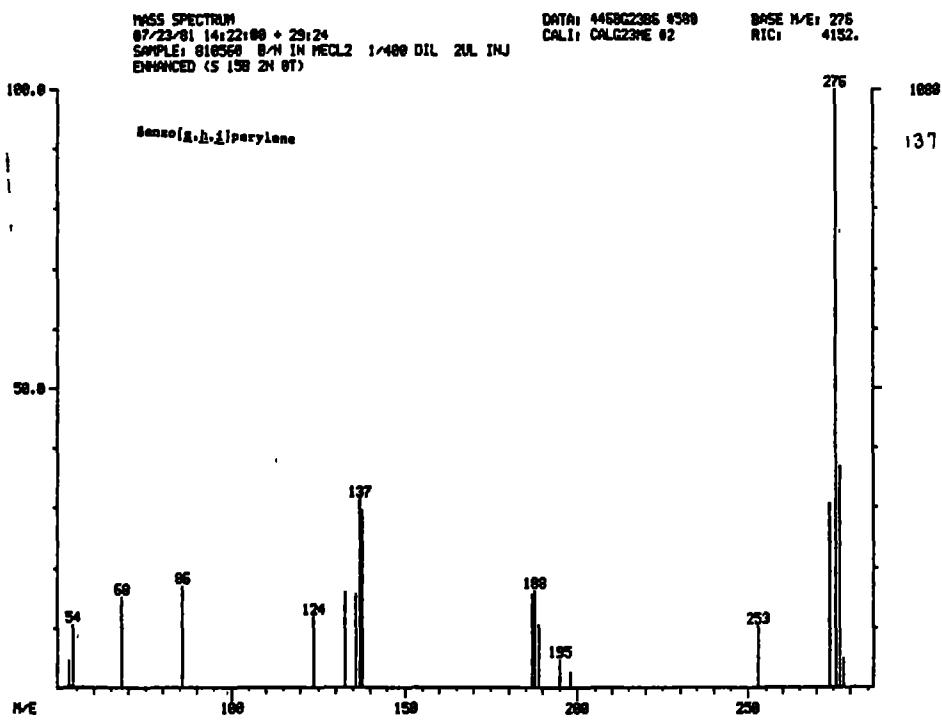


Figure 137. Mass spectrum of benzo[g,h,i]perylene in sample 810560.

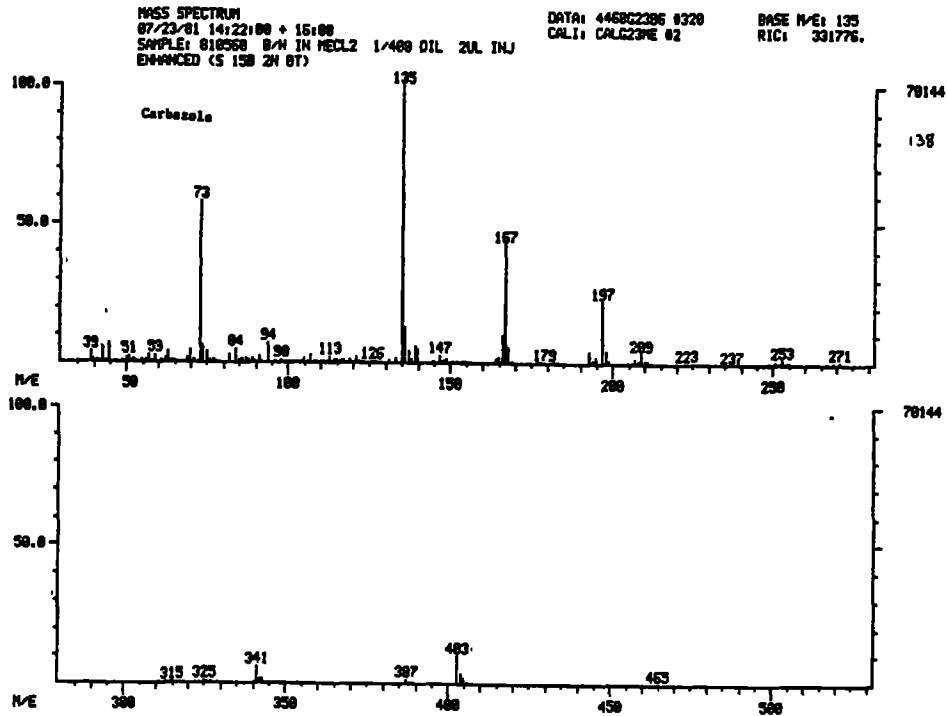


Figure 138. Mass spectrum of carbazole in sample 810560.

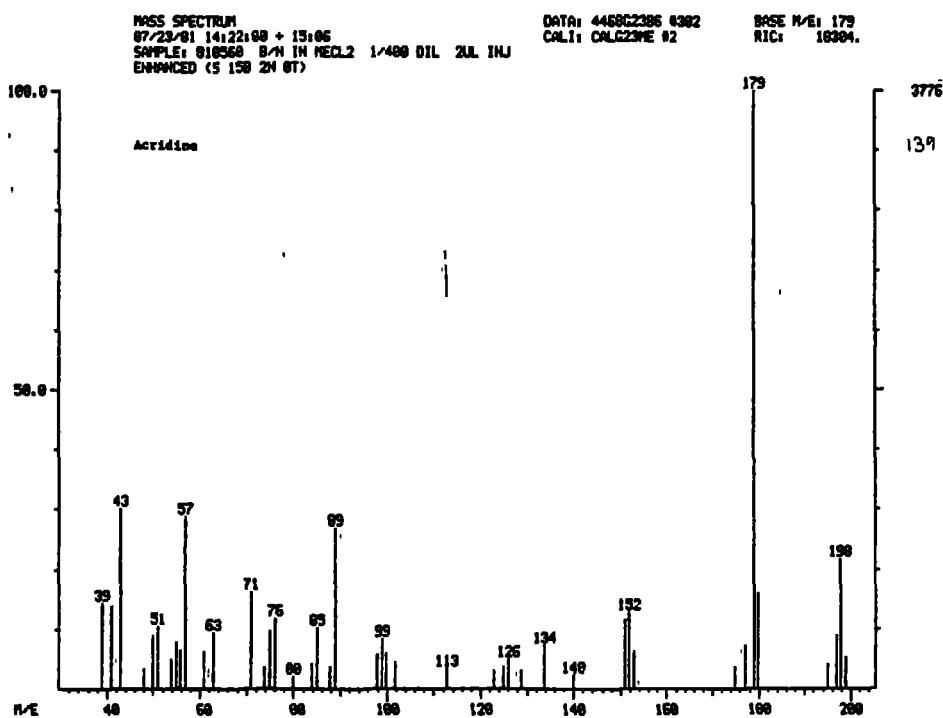


Figure 139. Mass spectrum of acridine insample 810560.

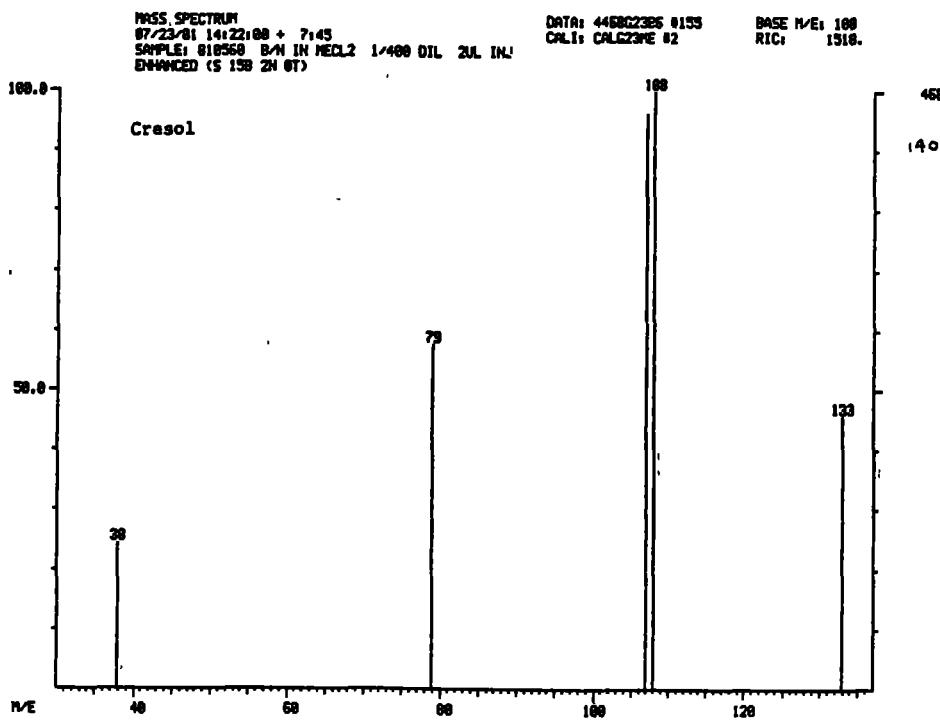


Figure 140. Mass spectrum of cresol in sample 810560.

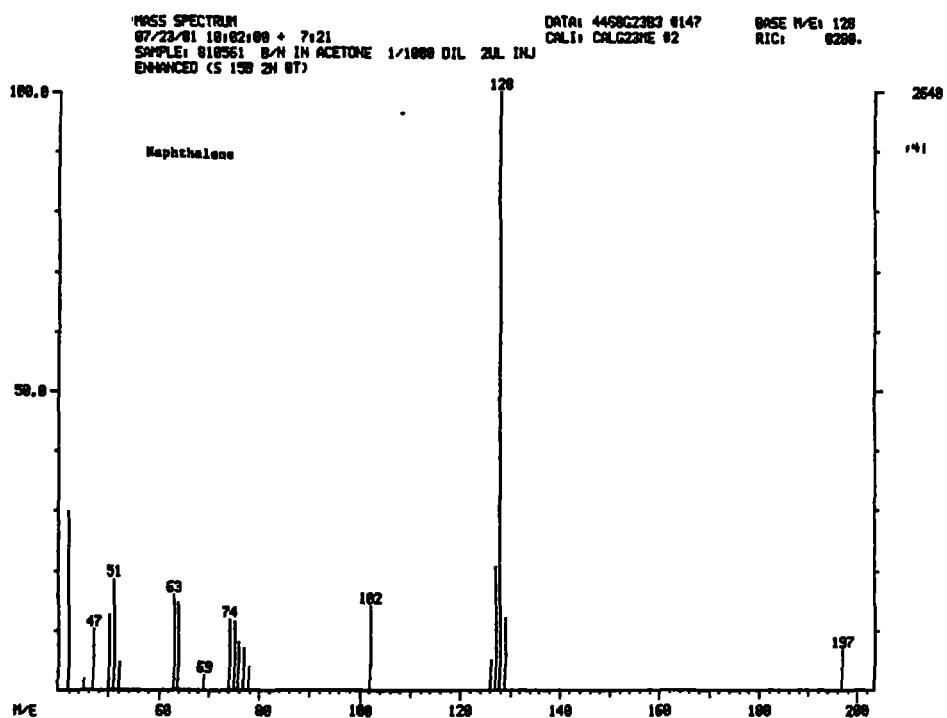


Figure 141. Mass spectrum of naphthalene in sample 810561.

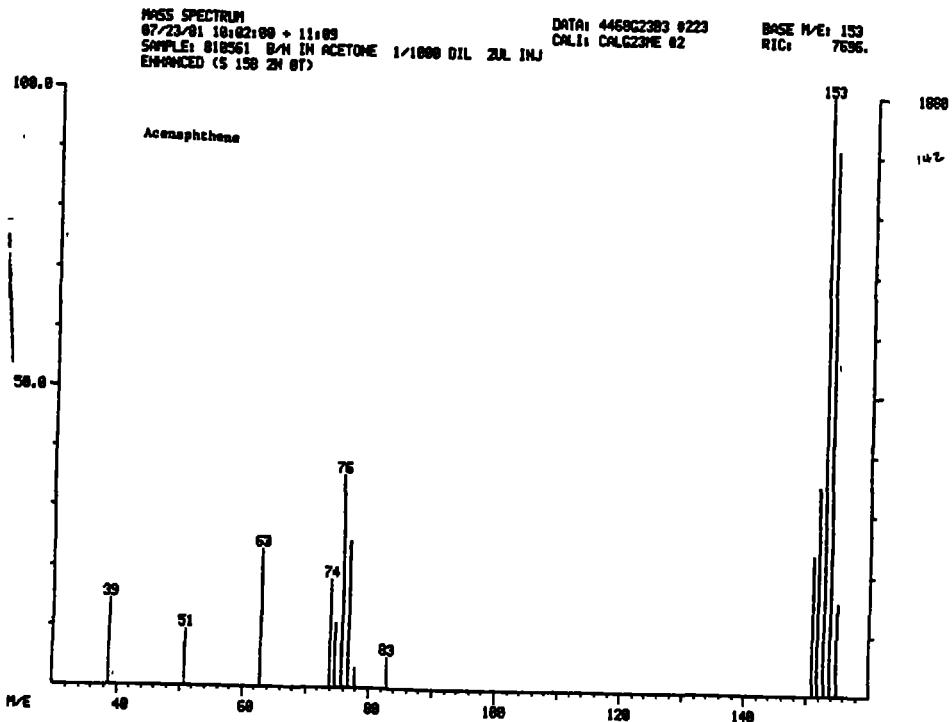


Figure 142. Mass spectrum of acenaphthene in sample 810561.

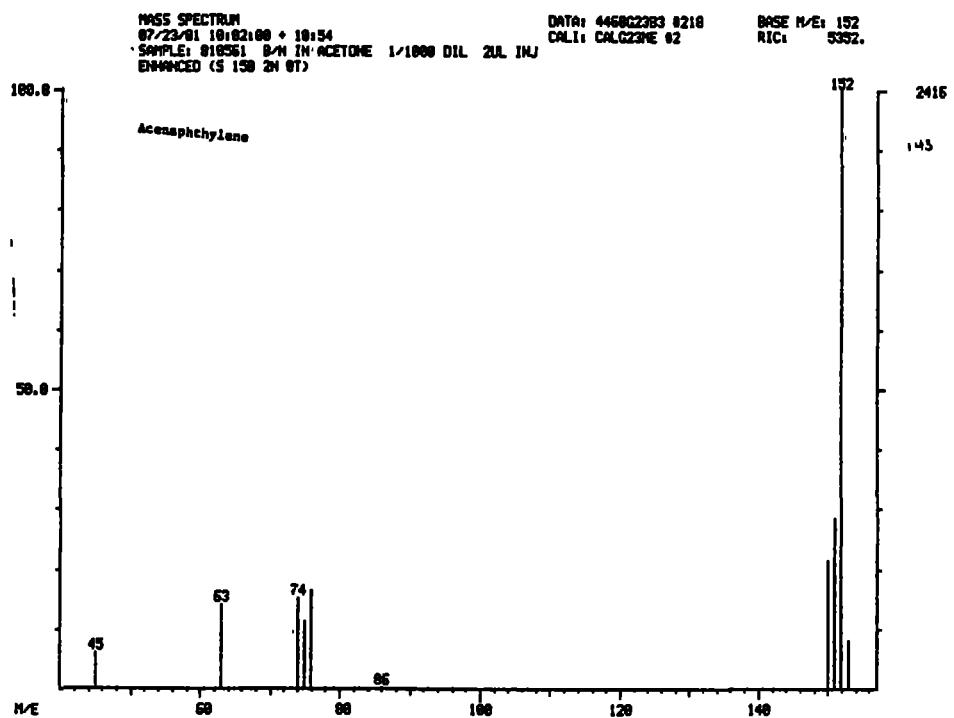


Figure 143. Mass spectrum of acenaphthylene in sample 810561.

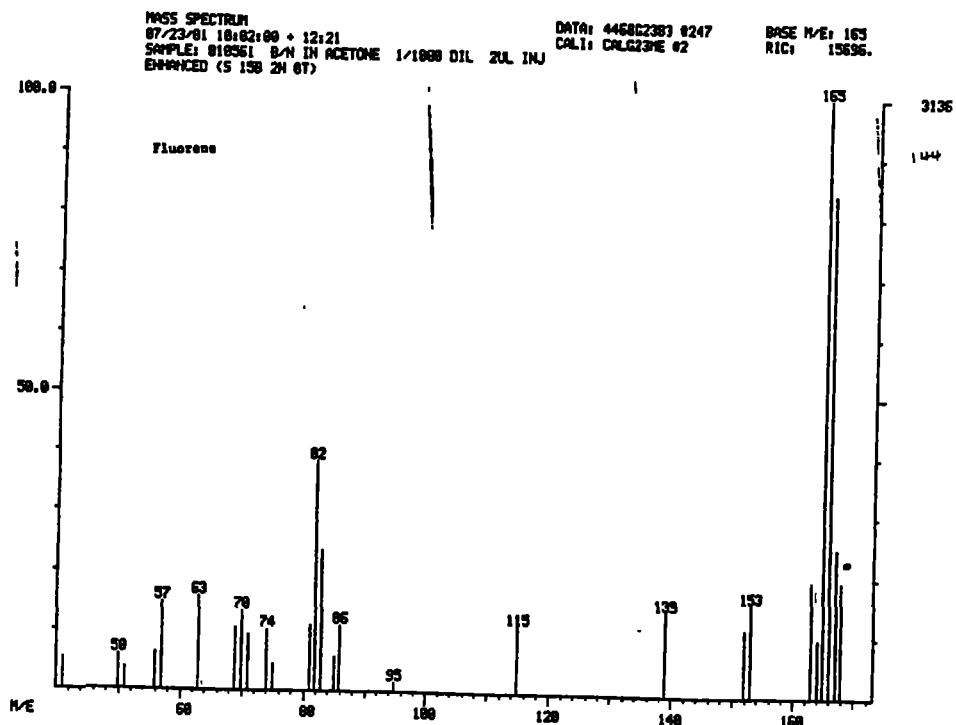


Figure 144. Mass spectrum of fluorene in sample 810561.

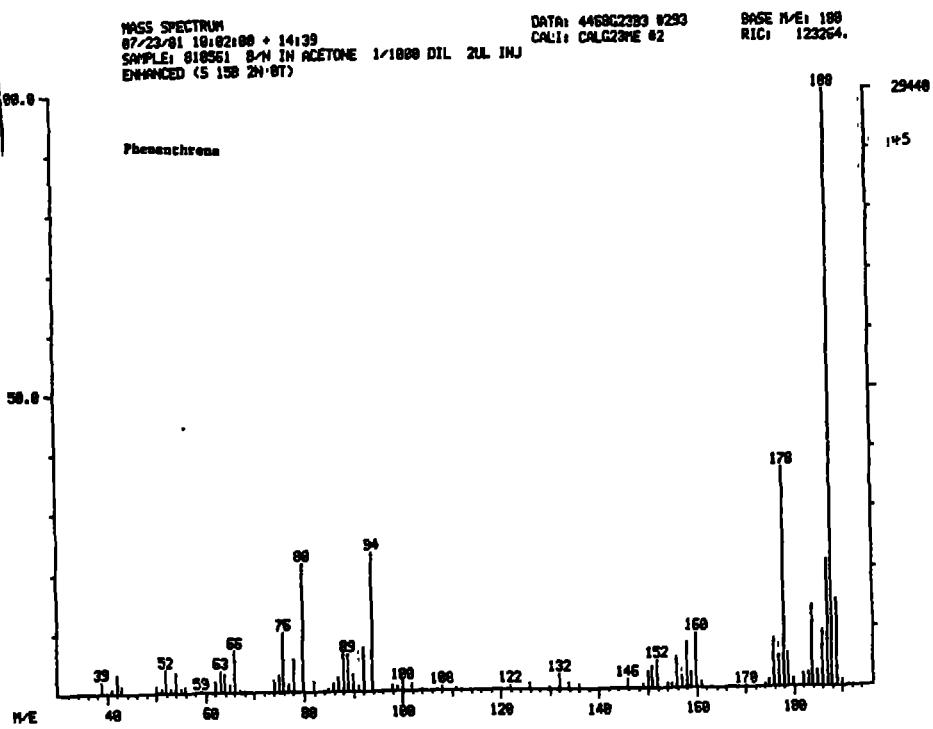


Figure 145. Mass spectrum of phenanthrene in sample 810561.

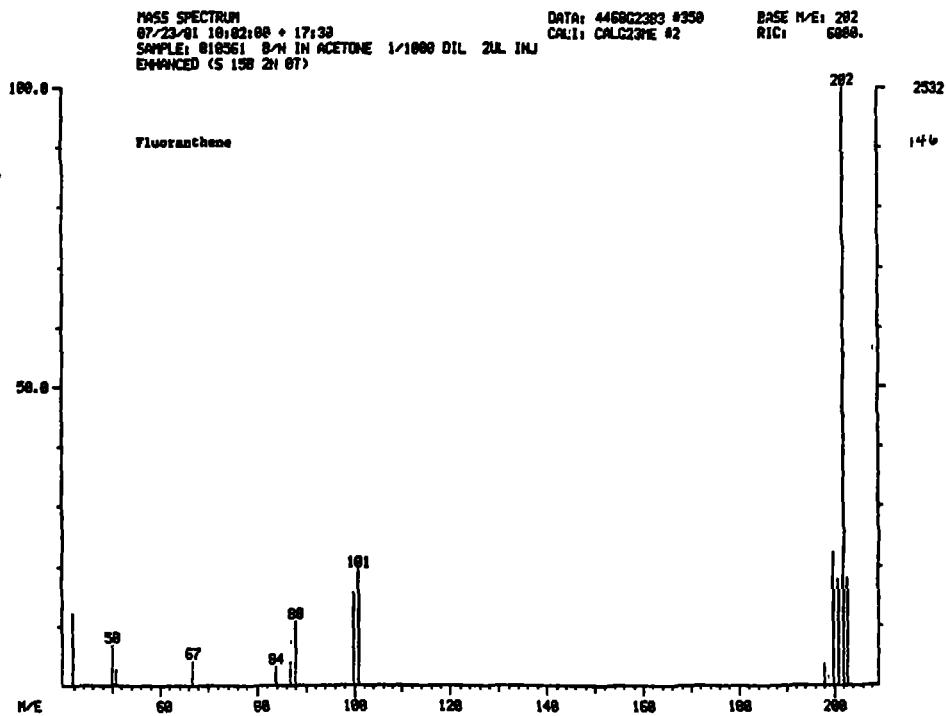


Figure 146. Mass spectrum of fluoranthene in sample 810561.

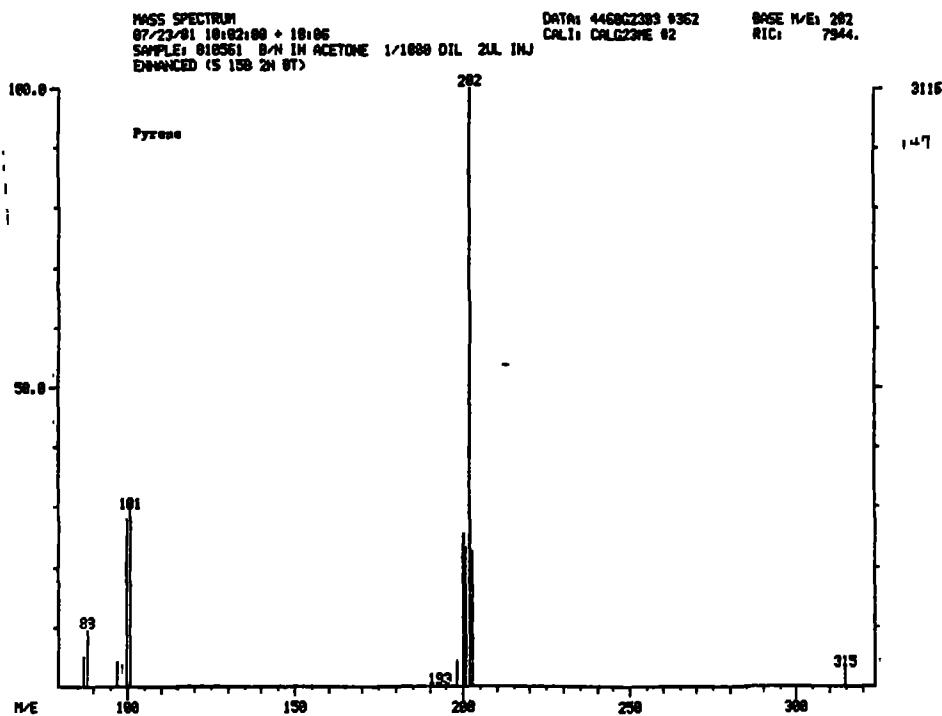


Figure 147. Mass spectrum of pyrene in sample 810561.

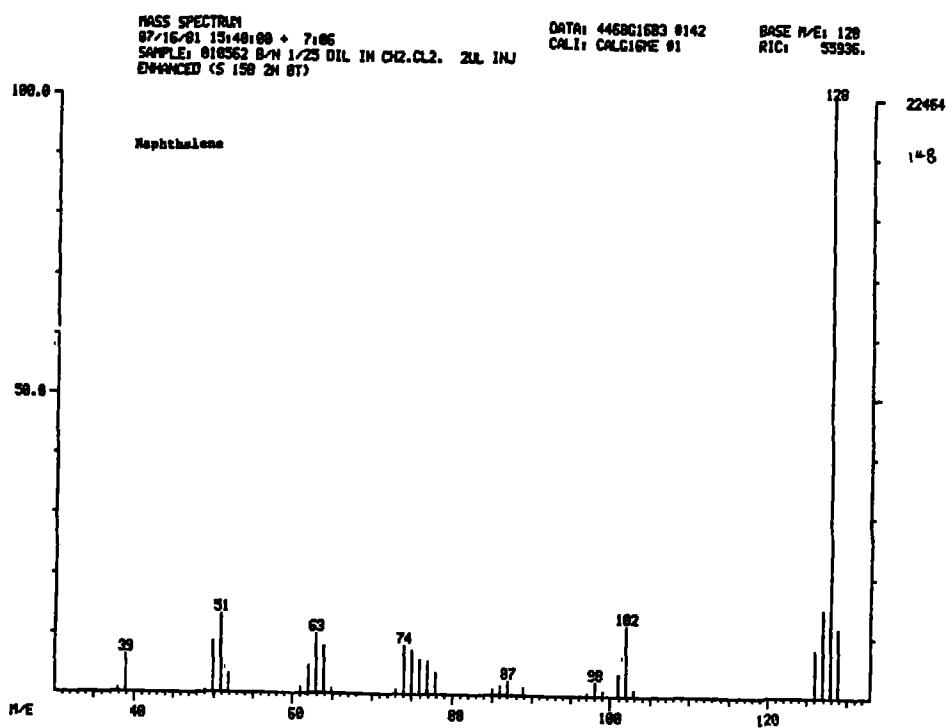


Figure 148. Mass spectrum of naphthalene in sample 810562.

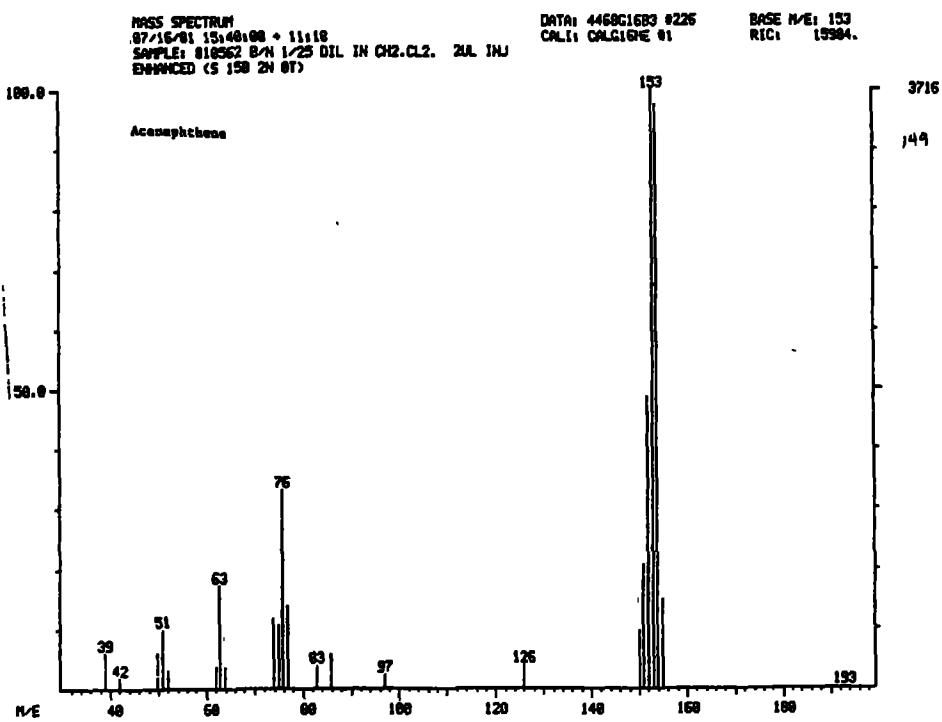


Figure 149. Mass spectrum of acenaphthene in sample 810562.

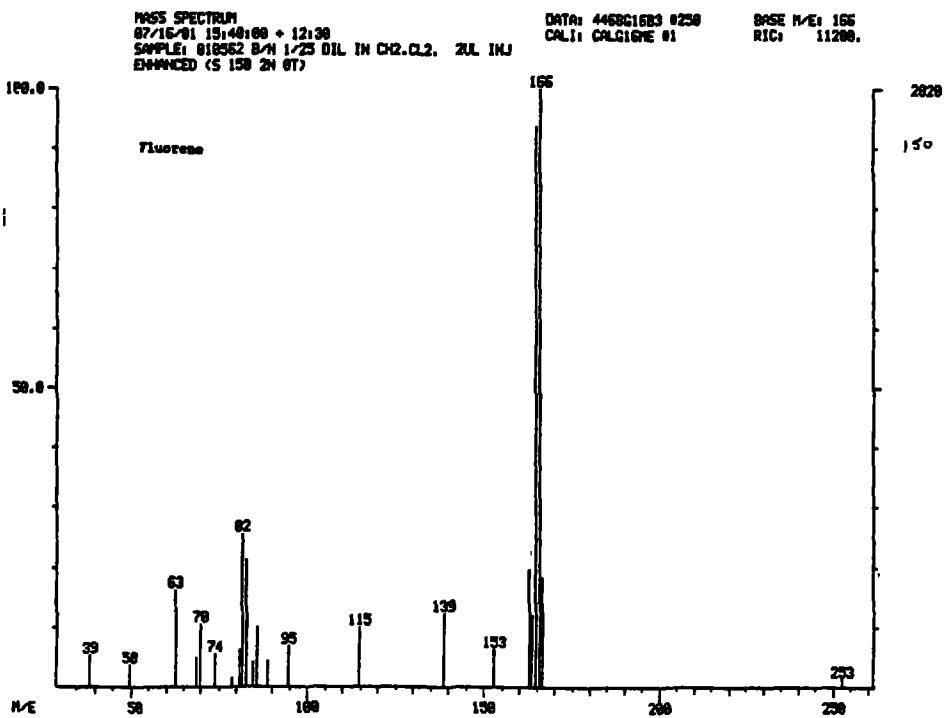


Figure 150. Mass spectrum of fluorene in sample 810562.

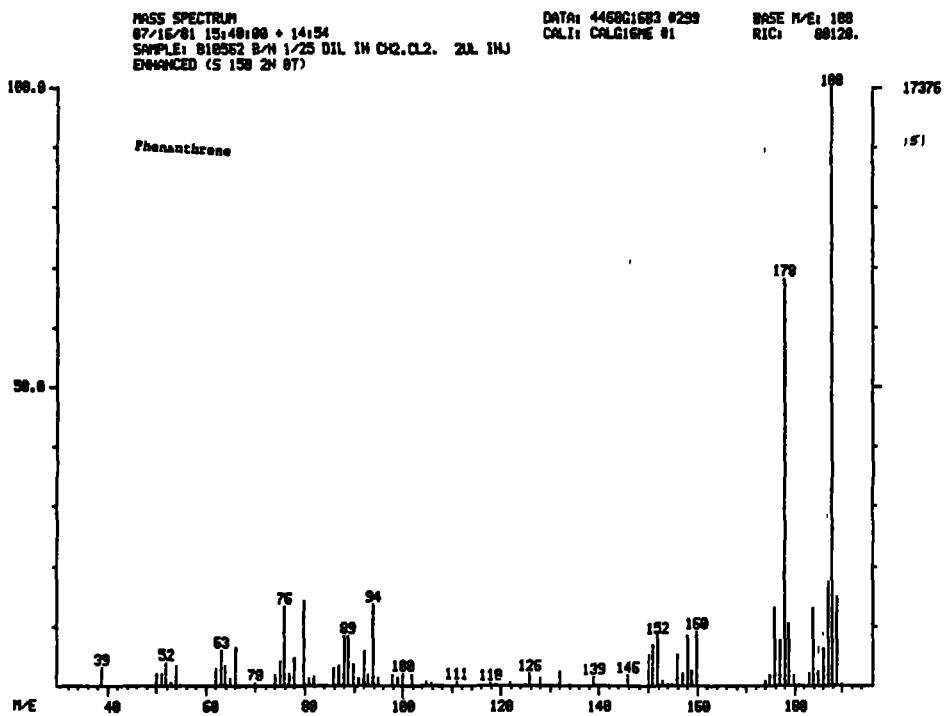


Figure 151. Mass spectrum of phenanthrene in sample 810562.

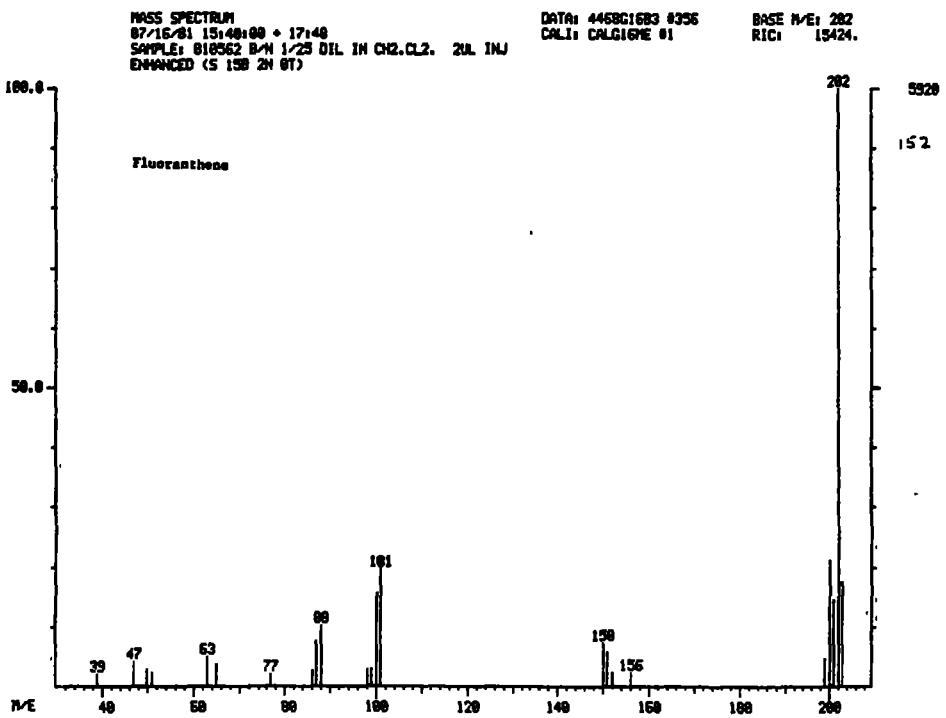


Figure 152. Mass spectrum of fluoranthene in sample 810562.

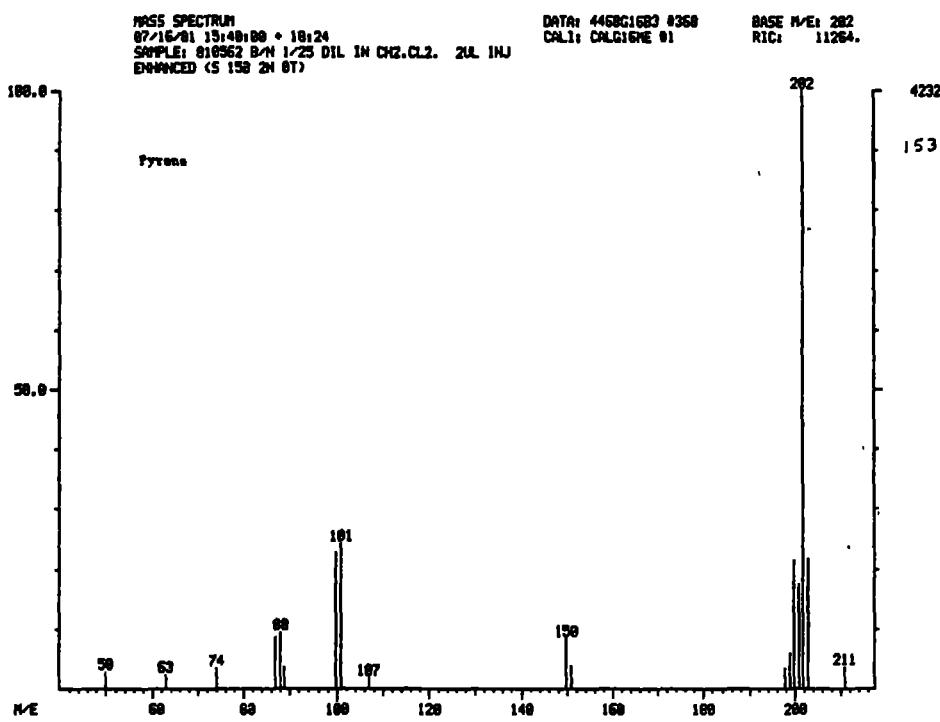


Figure 153. Mass spectrum of pyrene in sample 810562.

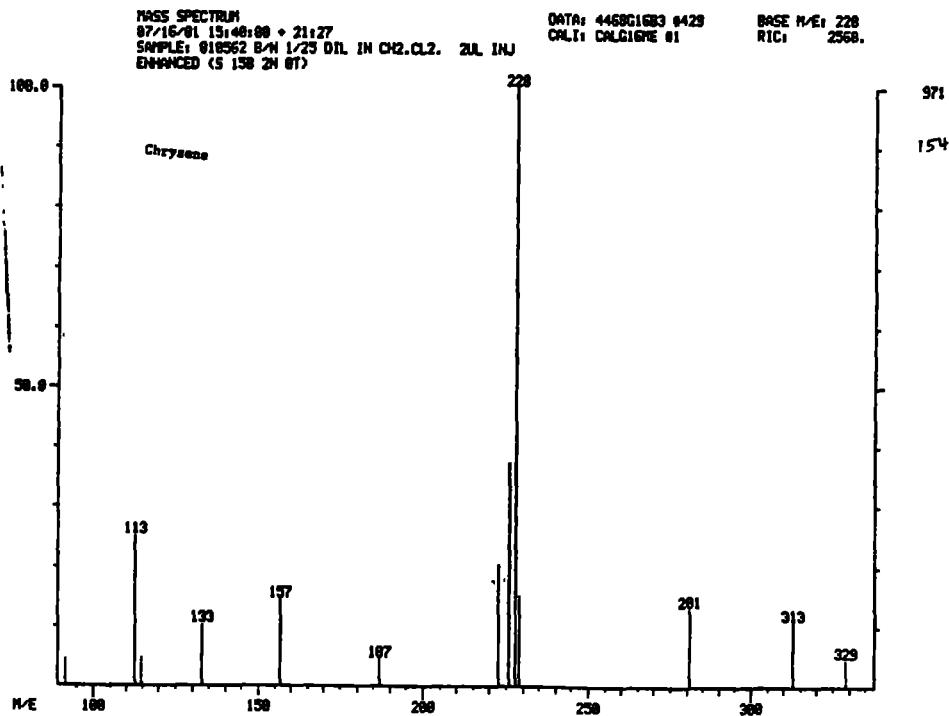


Figure 154. Mass spectrum of chrysene in sample 810562.

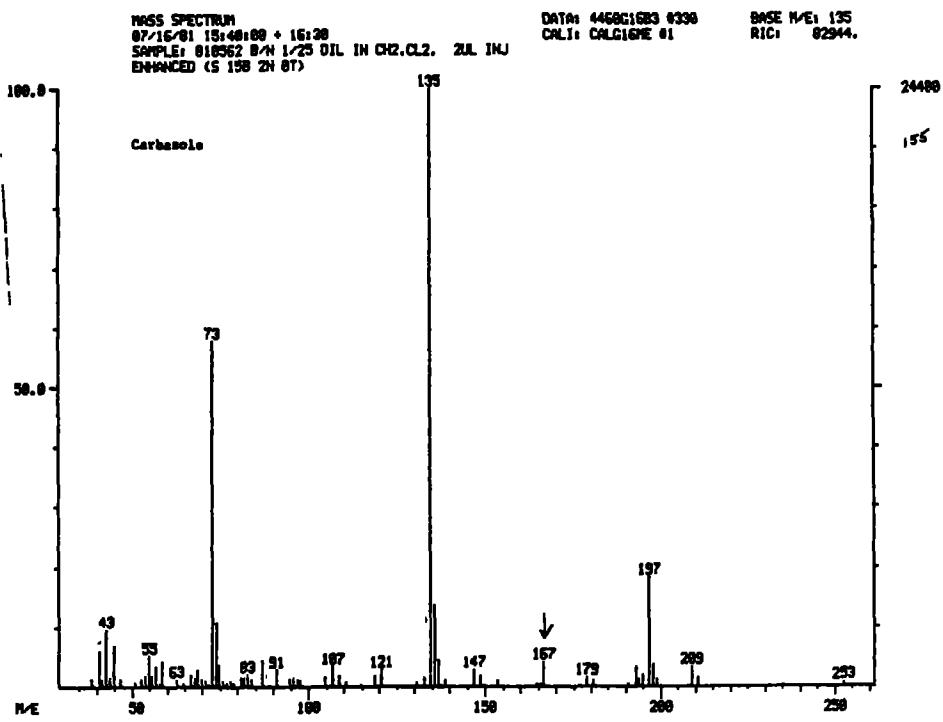


Figure 155. Mass spectrum of carbazole in sample 810562.

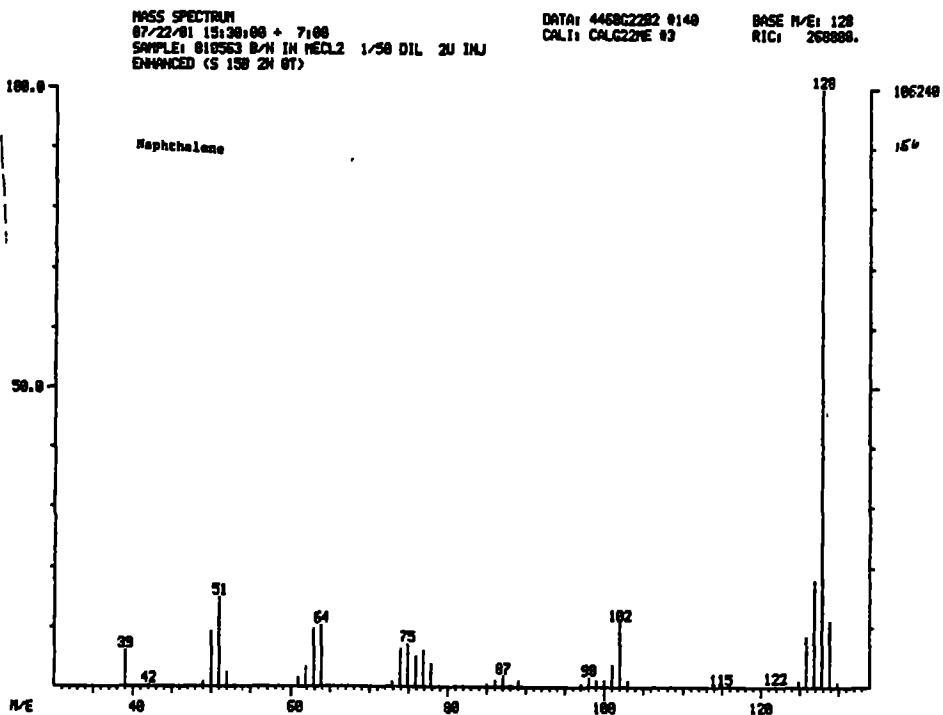


Figure 156. Mass spectrum of naphthalene in sample 810563.

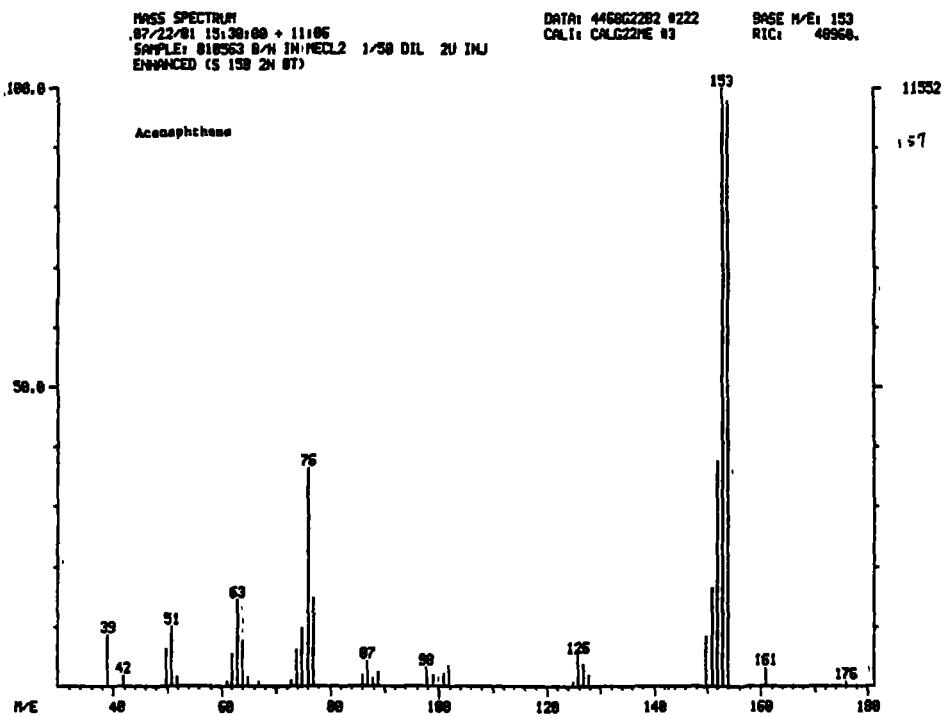


Figure 157. Mass spectrum of acenaphthene in sample 810563.

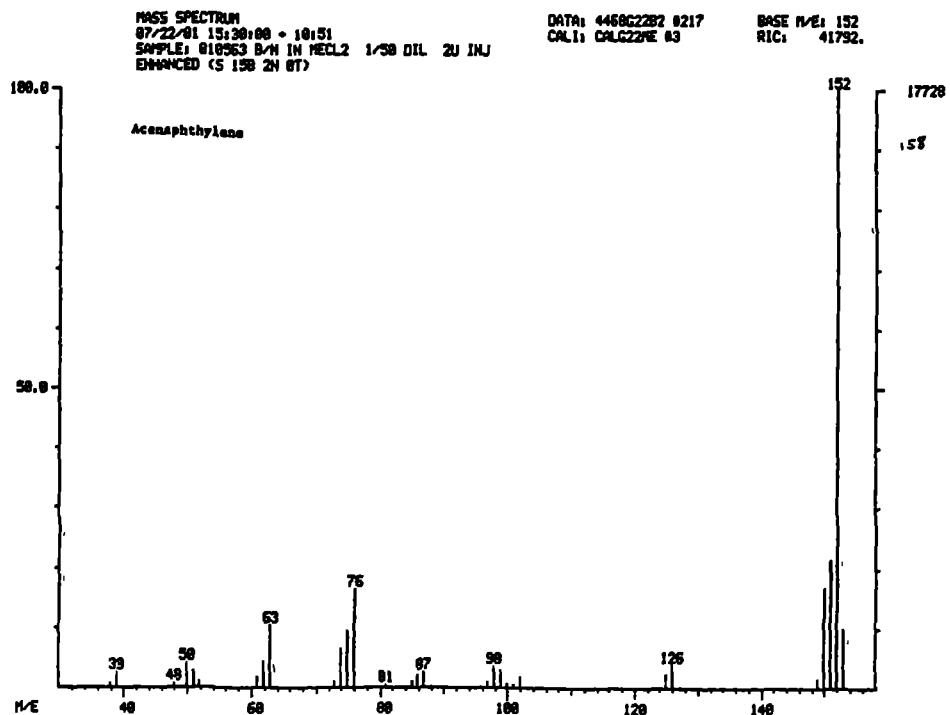


Figure 158. Mass spectrum of acenaphthylene in sample 810563.

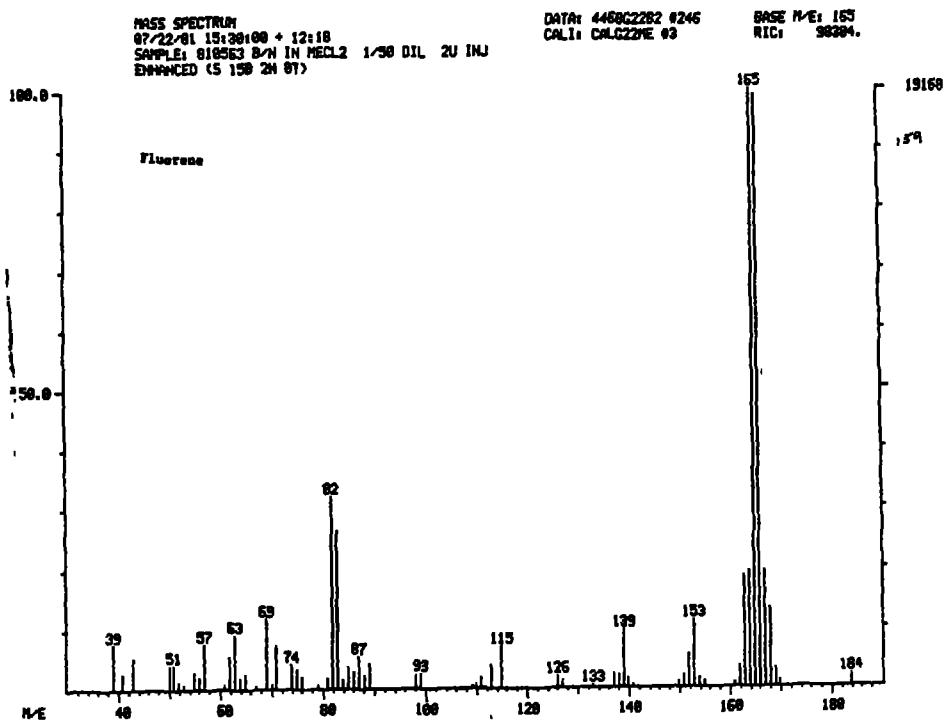


Figure 159. Mass spectrum of fluorene in sample 810563.

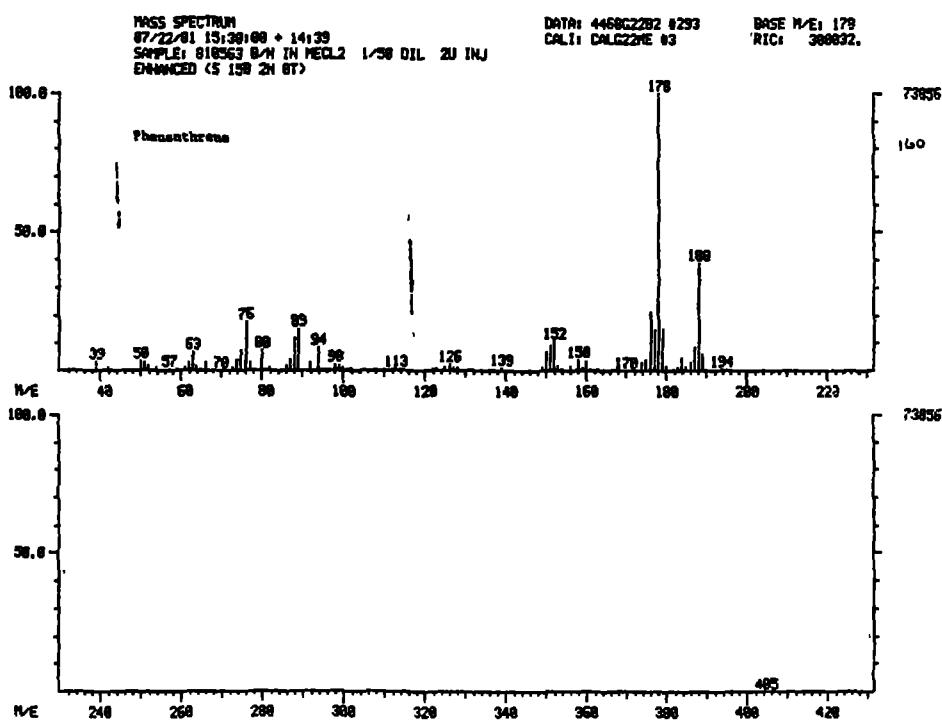


Figure 160. Mass spectrum of phenanthrene in sample 810563.

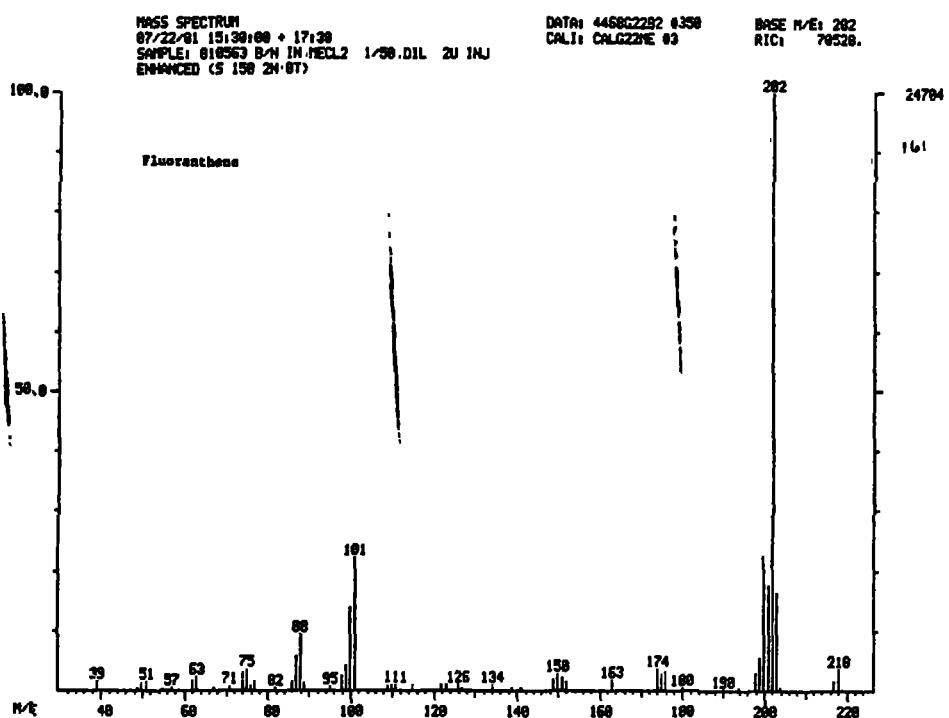


Figure 161. Mass spectrum of fluoranthene in sample 810563.

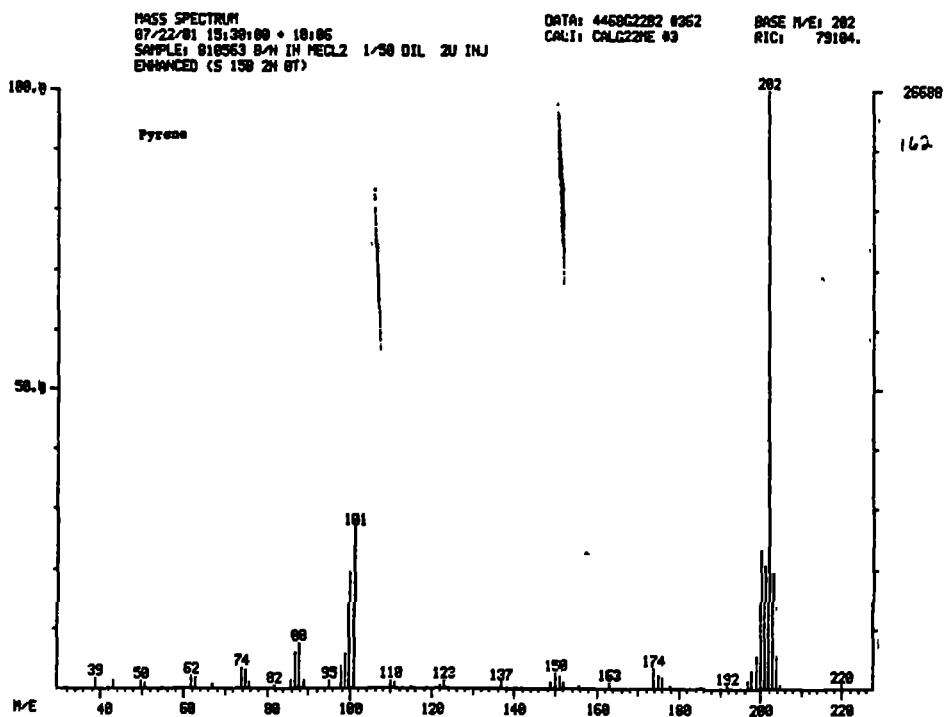


Figure 162. Mass spectrum of pyrene in sample 810563.

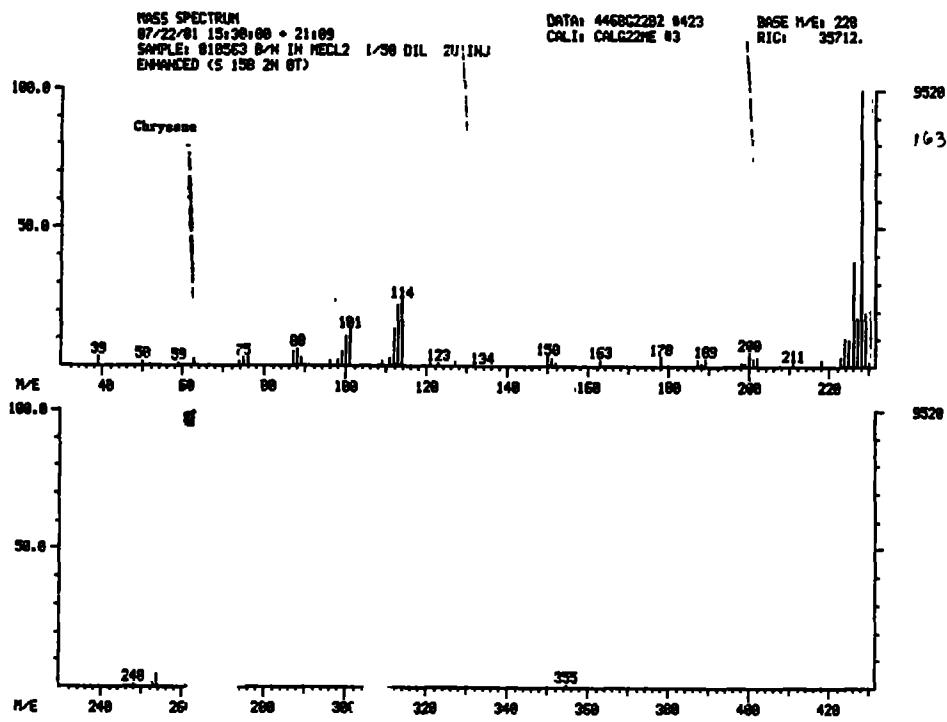


Figure 163. Mass spectrum of chrysene in sample 810563.

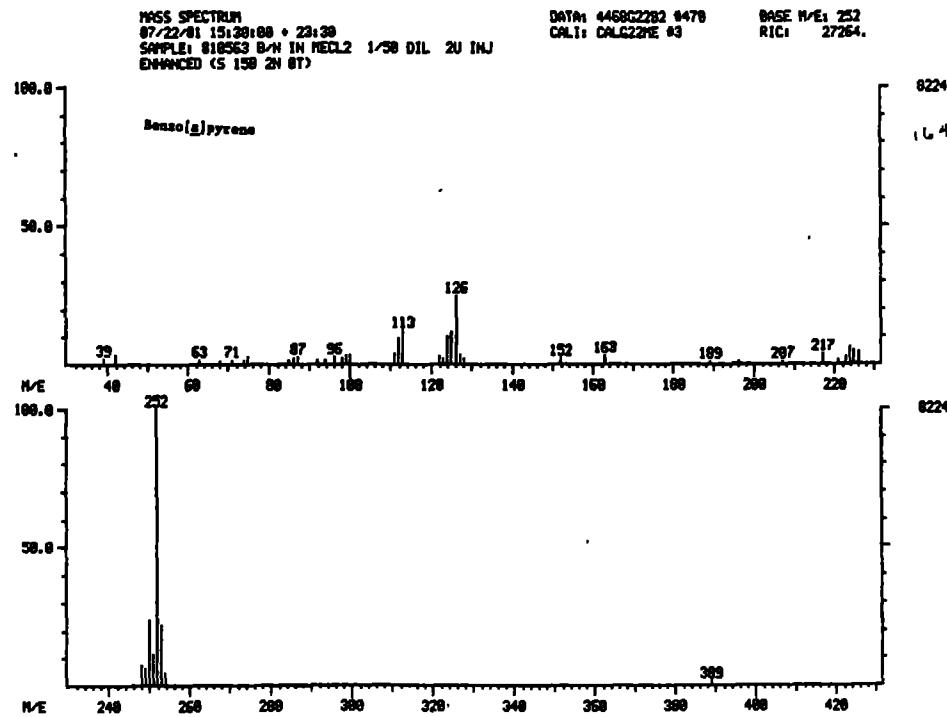


Figure 164. Mass spectrum of benzo[a]pyrene in sample 810563.

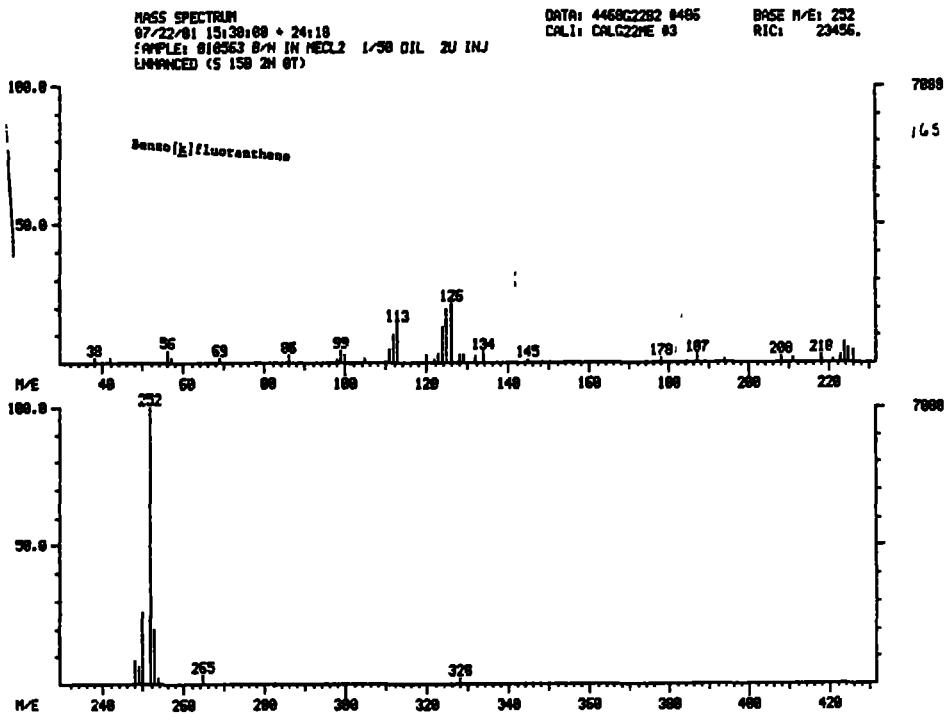


Figure 165. Mass spectrum of benzo[k]fluoranthene in sample 810563.

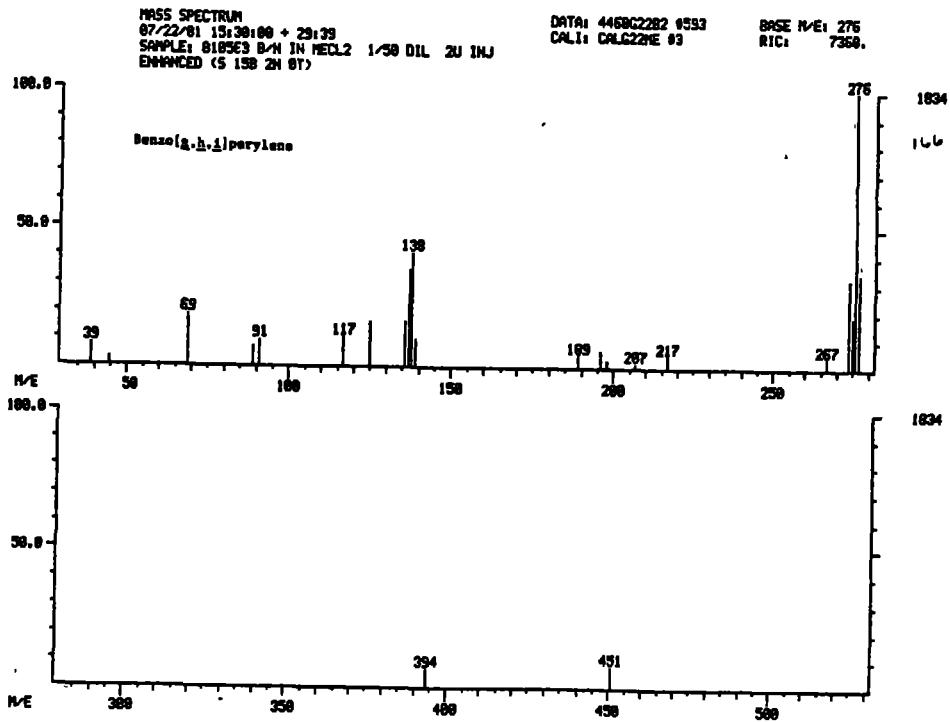


Figure 166. Mass spectrum of benzo[g,h,i]perylene in sample 810563.

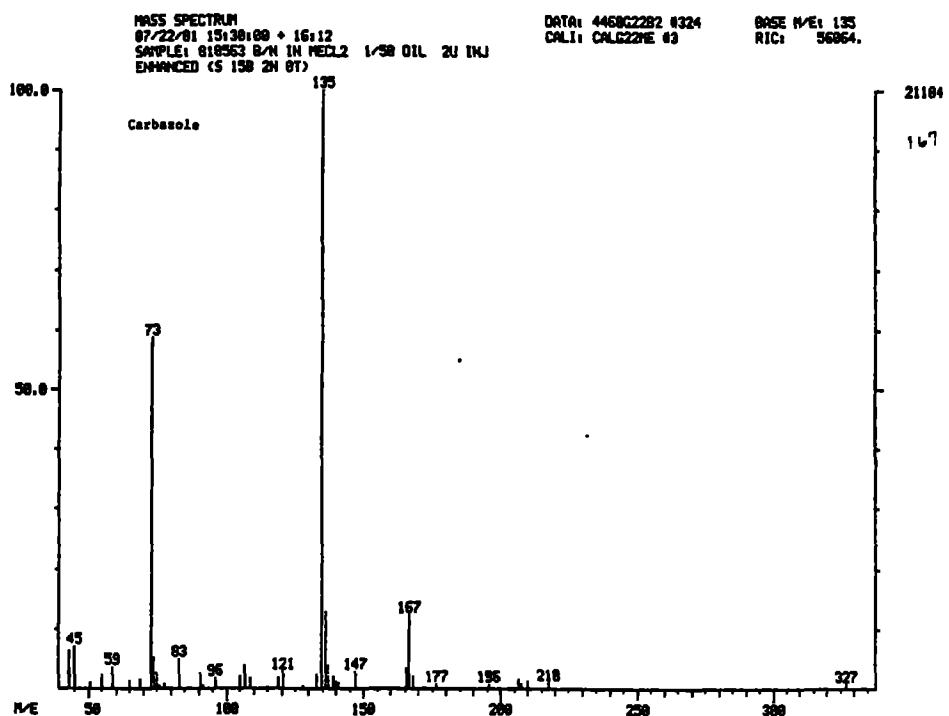


Figure 167. Mass spectrum of carbazole in sample 810563.

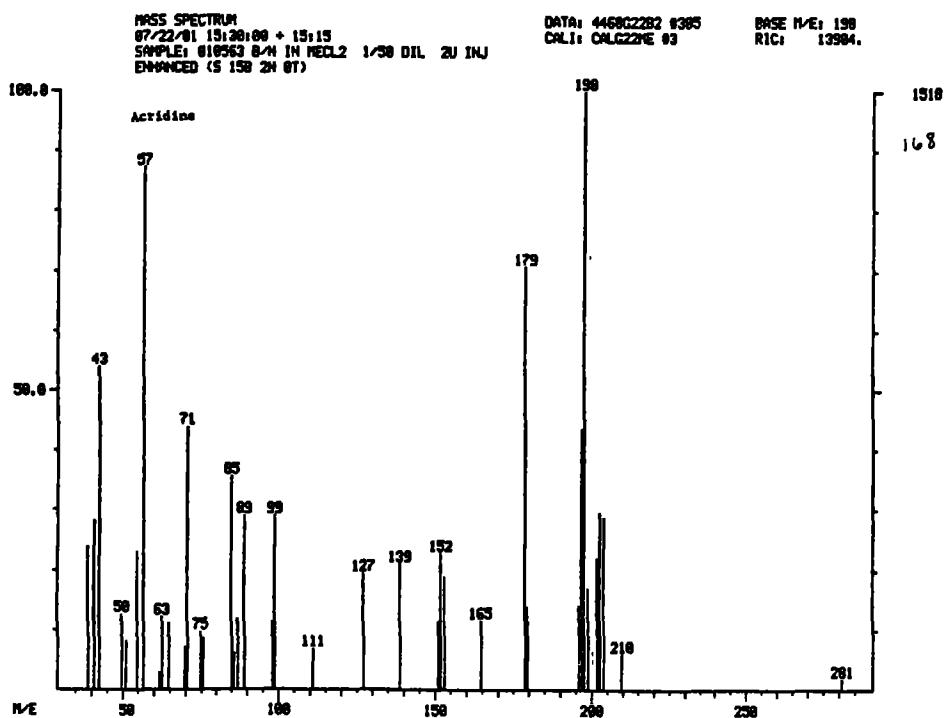


Figure 168. Mass spectrum of acridine in sample 810563.

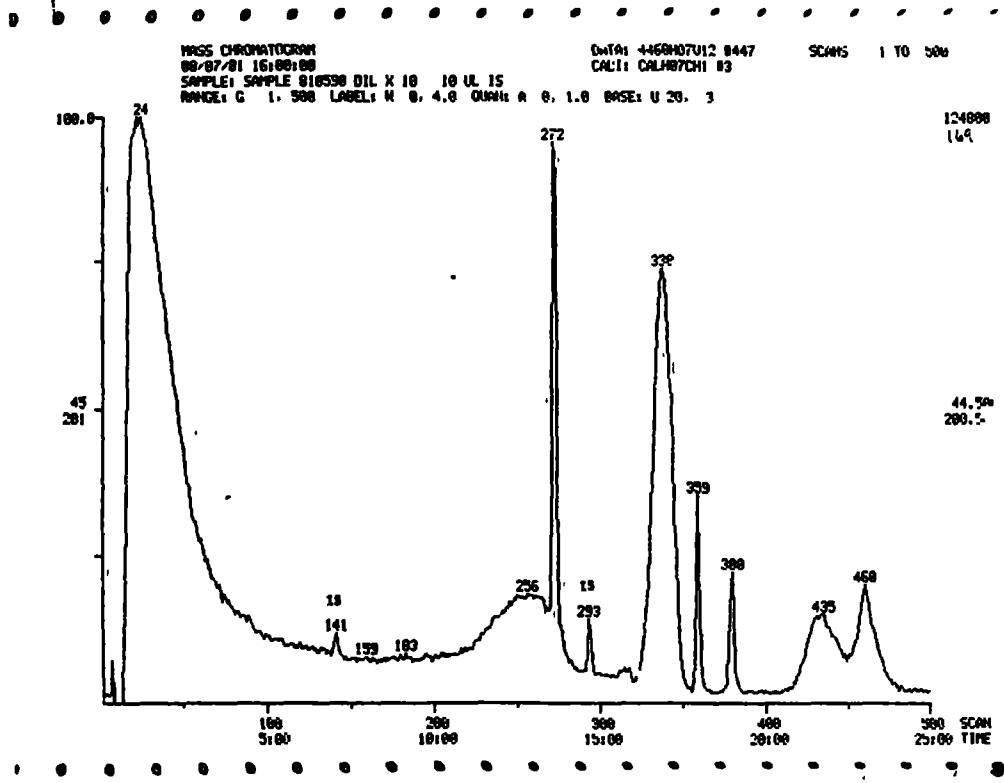


Figure 169. RIC of sample 810590 obtained by VOA method.

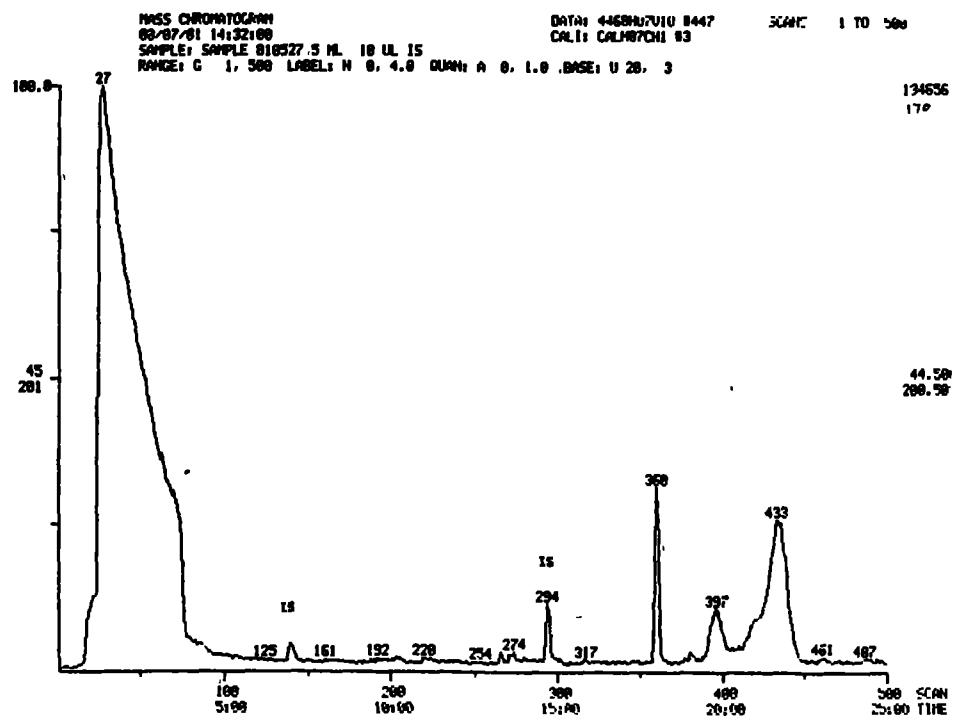


Figure 170. RIC of sample 810527 obtained by VOA method.

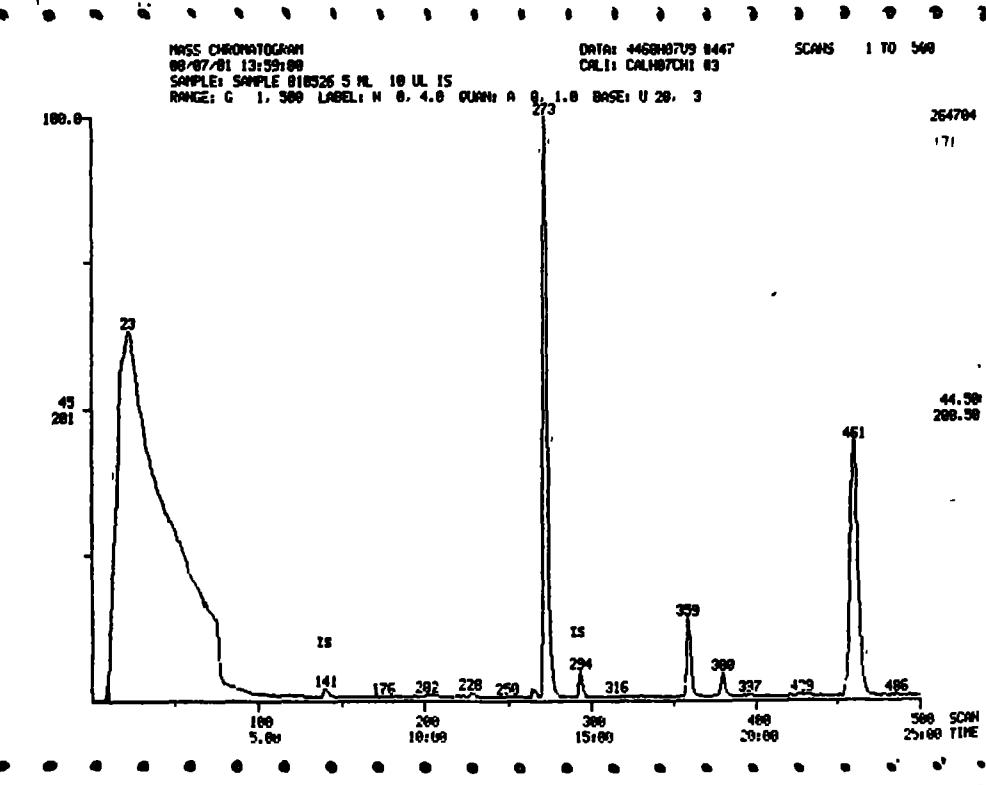


Figure 171. RIC of sample 810526 obtained by VOA method.

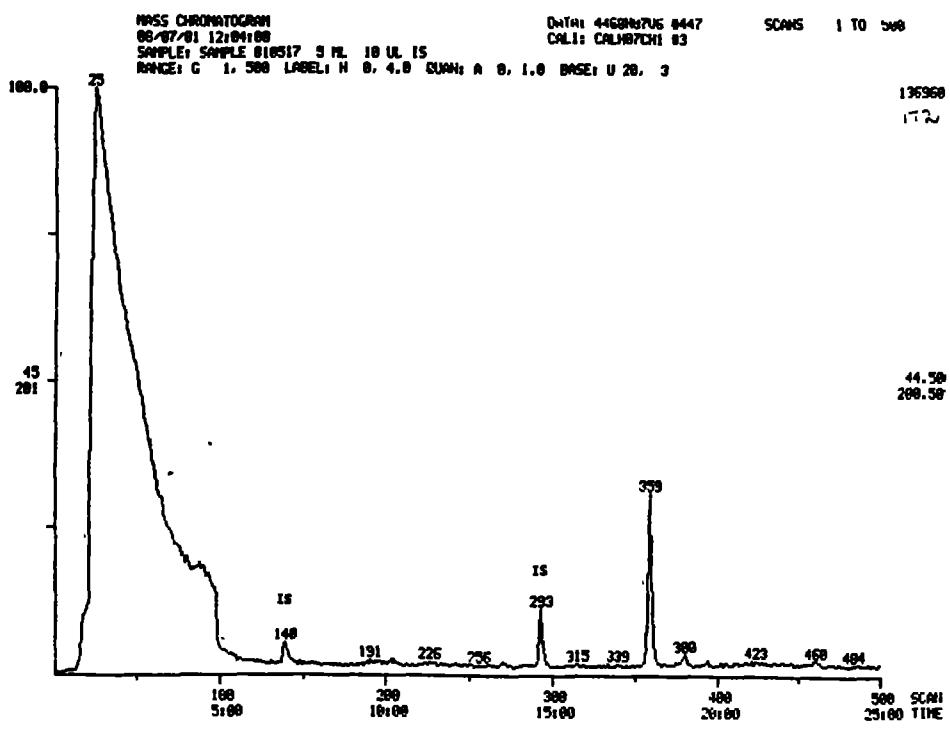


Figure 172. RIC of sample 810517 obtained by VOA method.

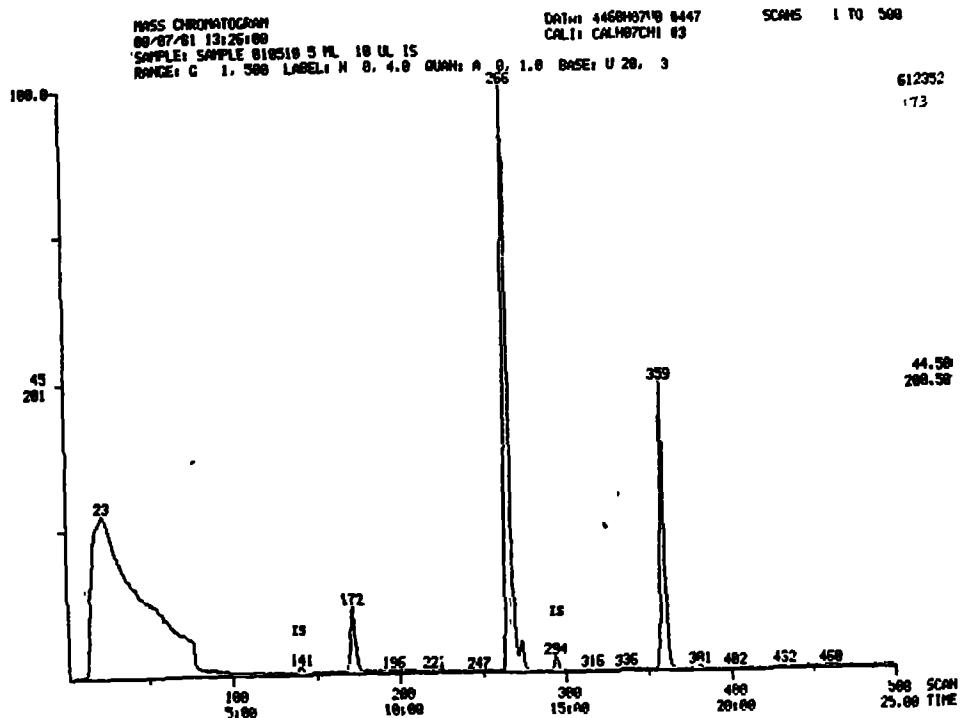


Figure 173. RIC of sample 810510 obtained by VOA method.

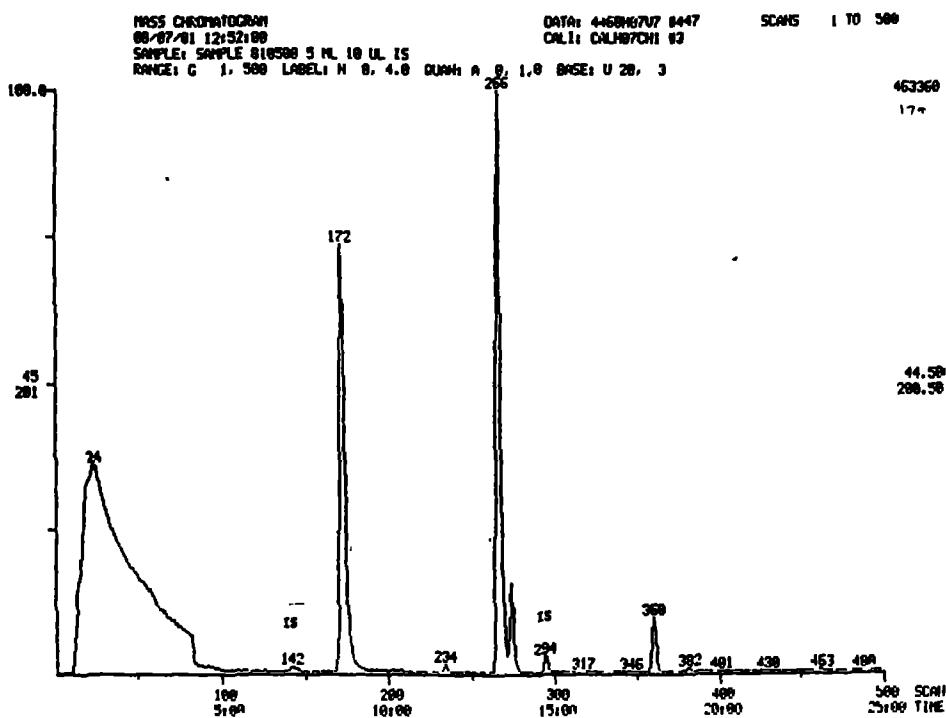


Figure 174. RIC of sample 810508 obtained by VOA method.

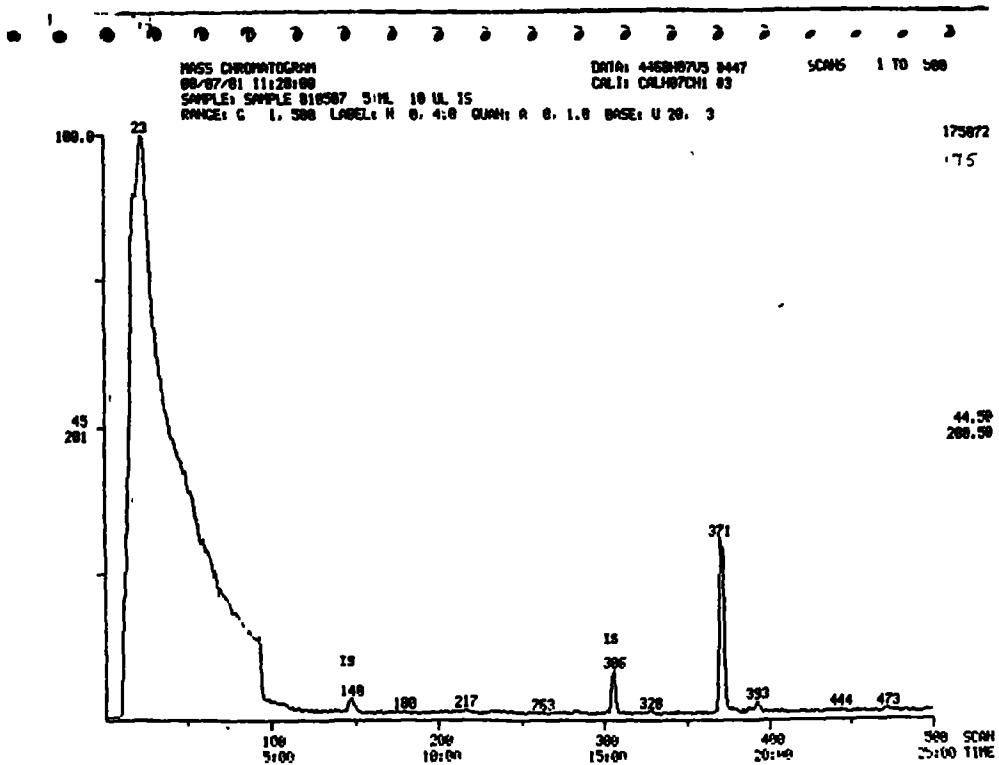


Figure 175. RIC of sample 810507 obtained by VOA method.

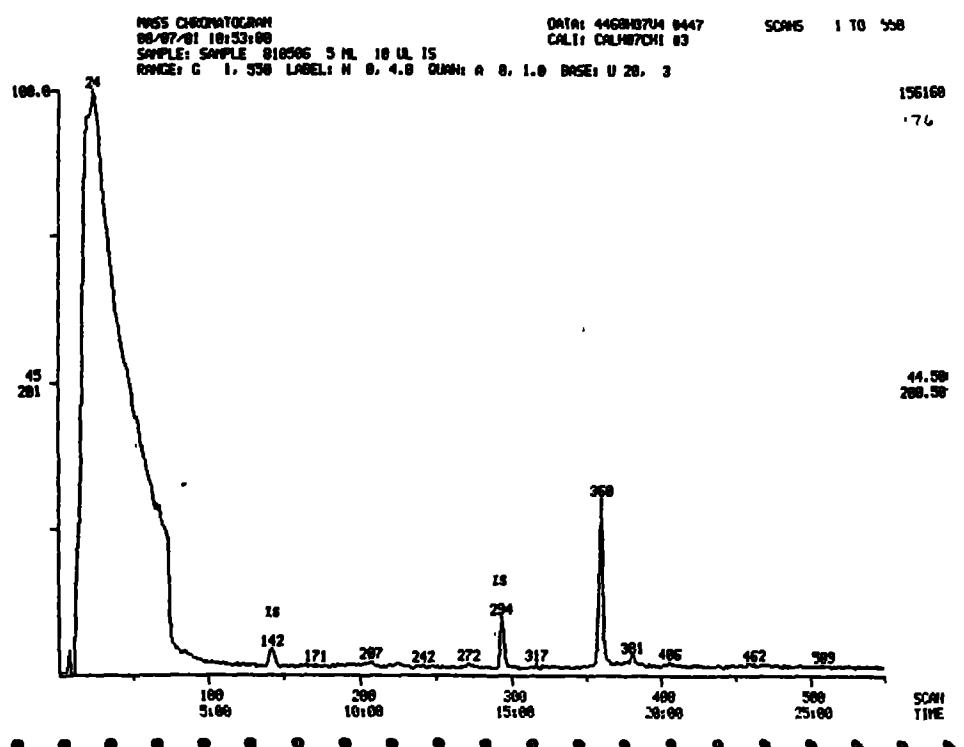


Figure 176. RIC of sample 810506 obtained by VOA method.

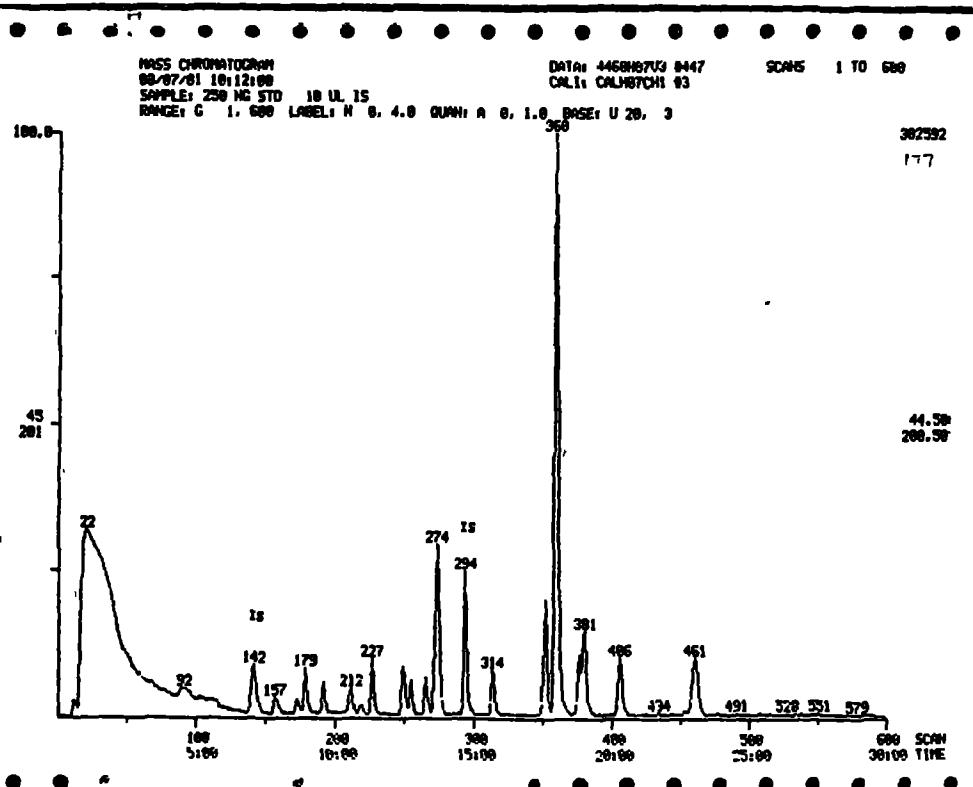


Figure 177. RIC of standard (250 ng) obtained by VOA method.

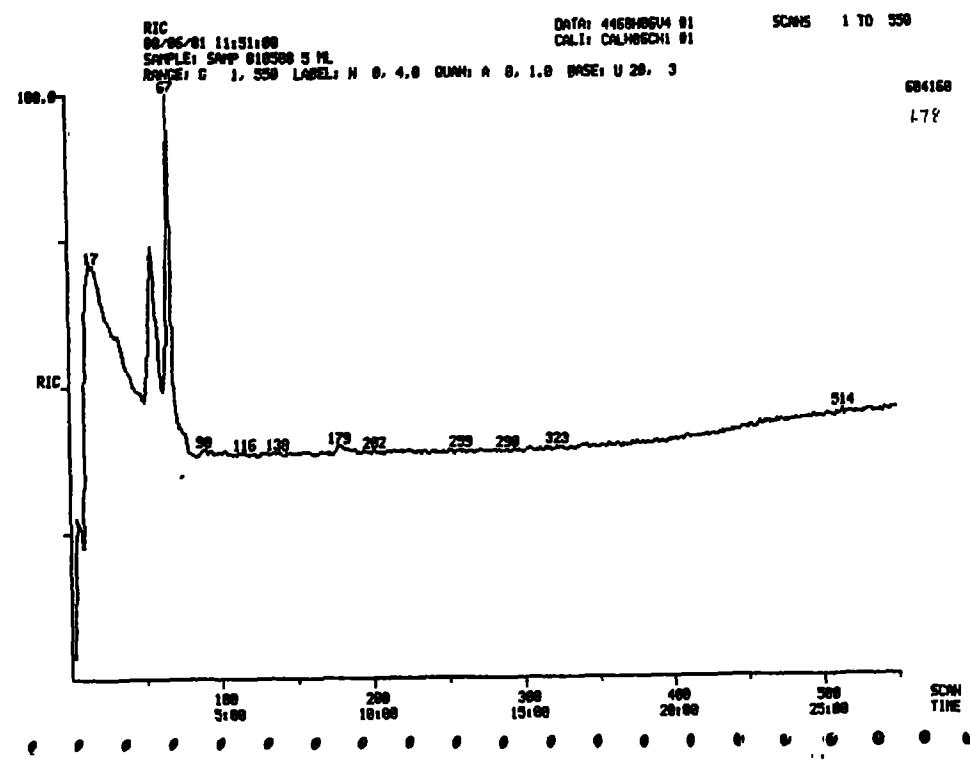


Figure 178. RIC of sample 810508 obtained by purgeable aromatics method (see text).

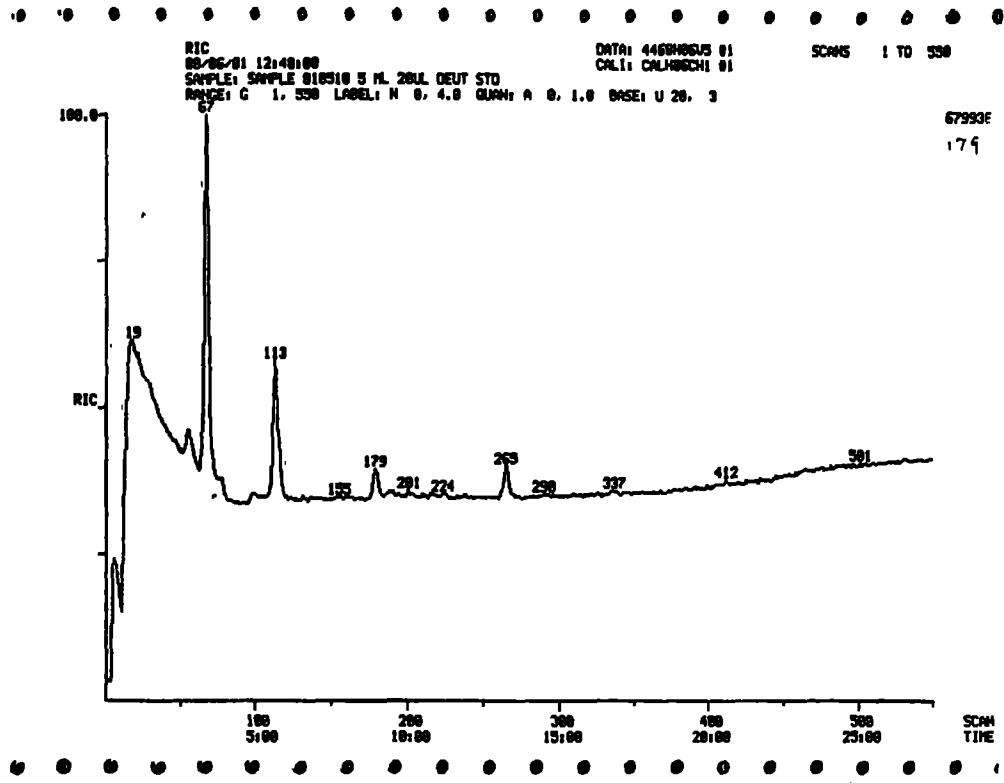


Figure 179. RIC of sample 810510 obtained by purgeable aromatics method (see text).

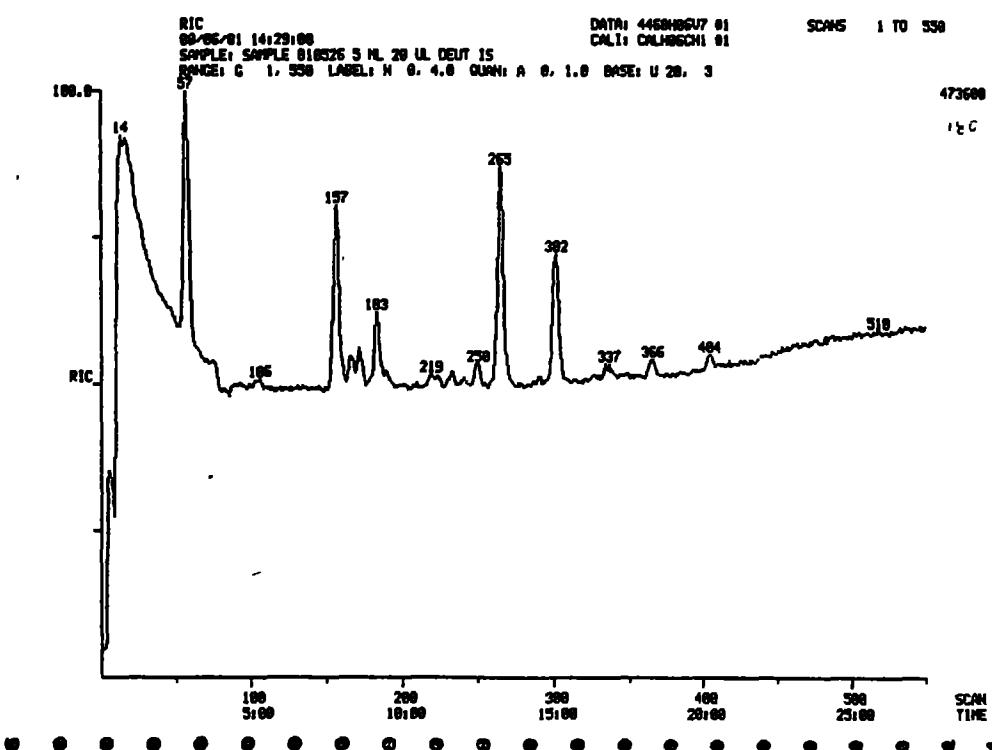


Figure 180. RIC of sample 810526 obtained by purgeable aromatics method (see text).

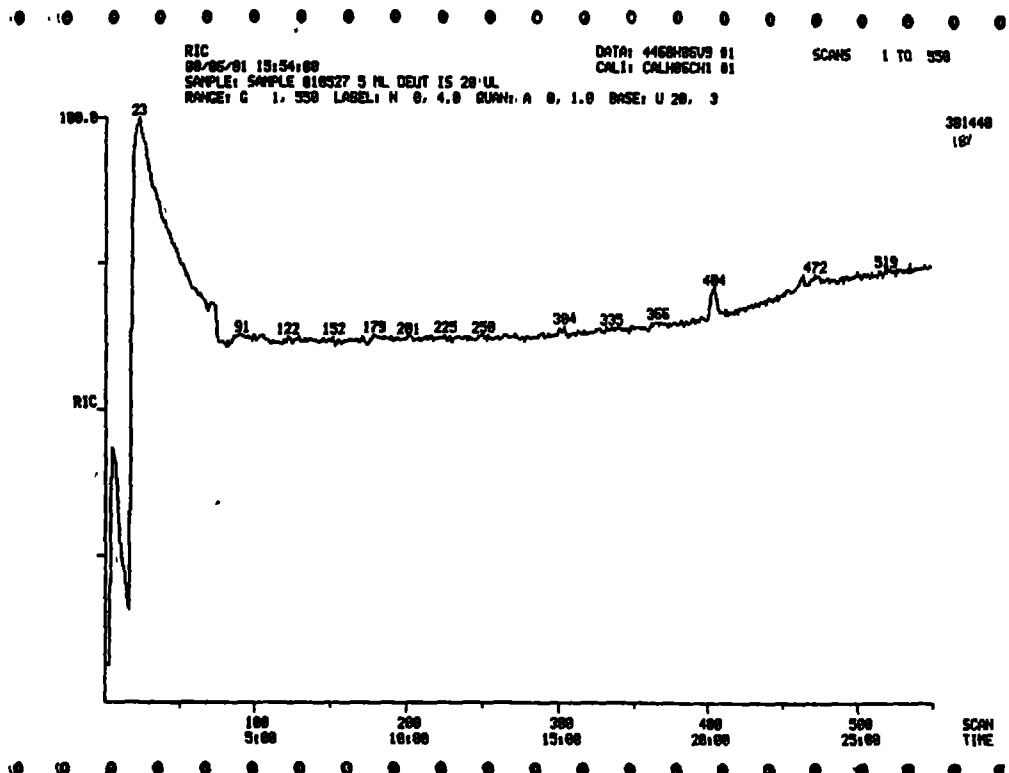


Figure 181. RIC of sample 810527 obtained by purgeable aromatics method (see text).

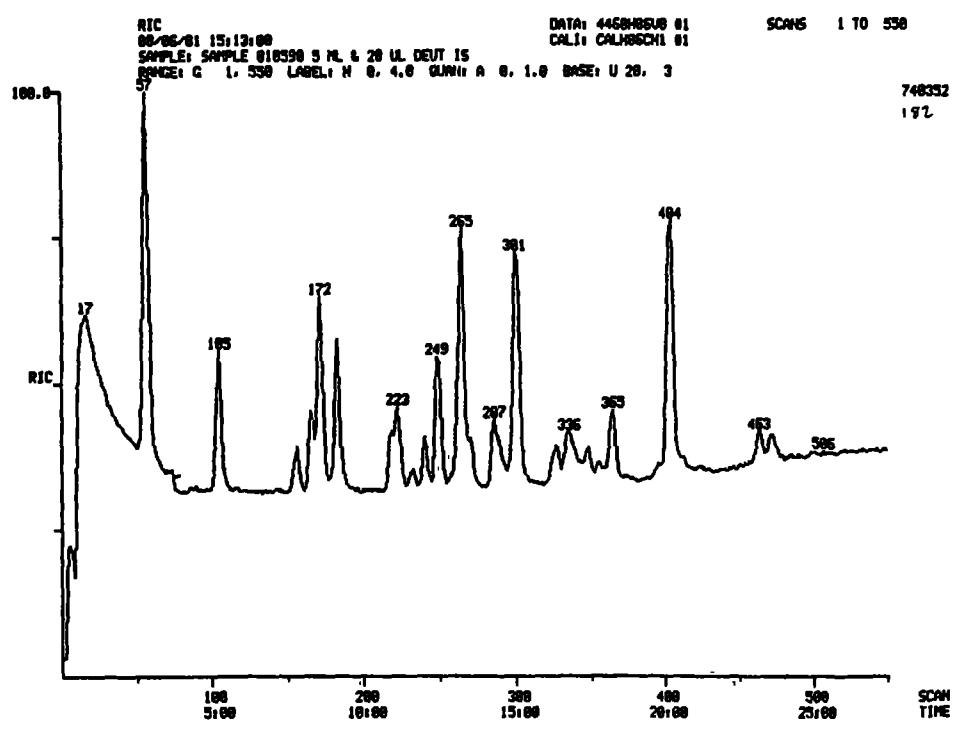


Figure 182. RIC of sample 810590 obtained by purgeable aromatics method (see text).

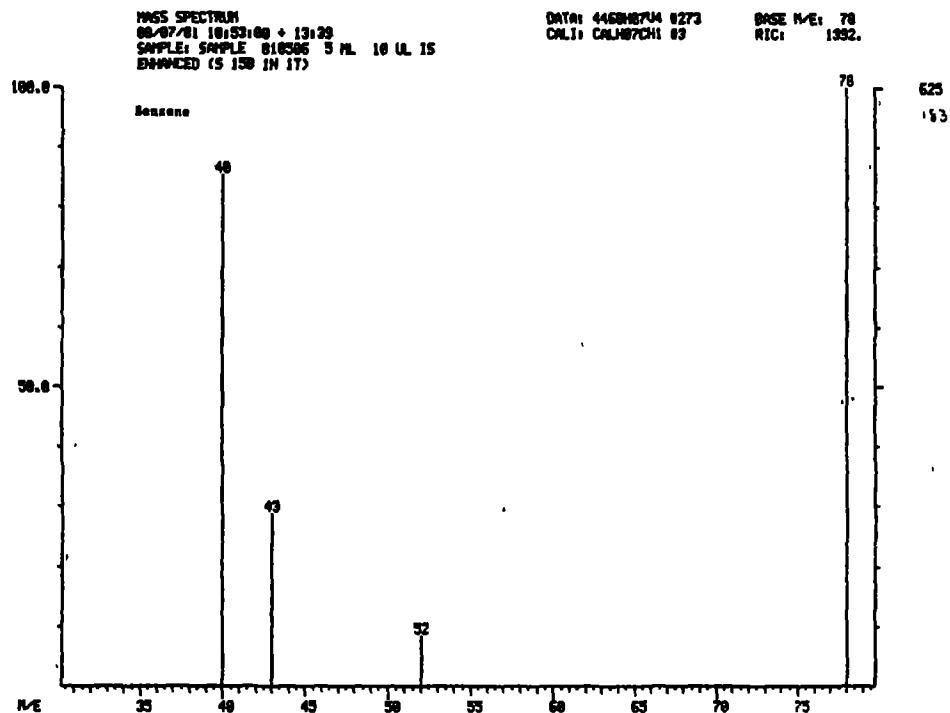


Figure 183. Mass spectrum of benzene in sample 810506.

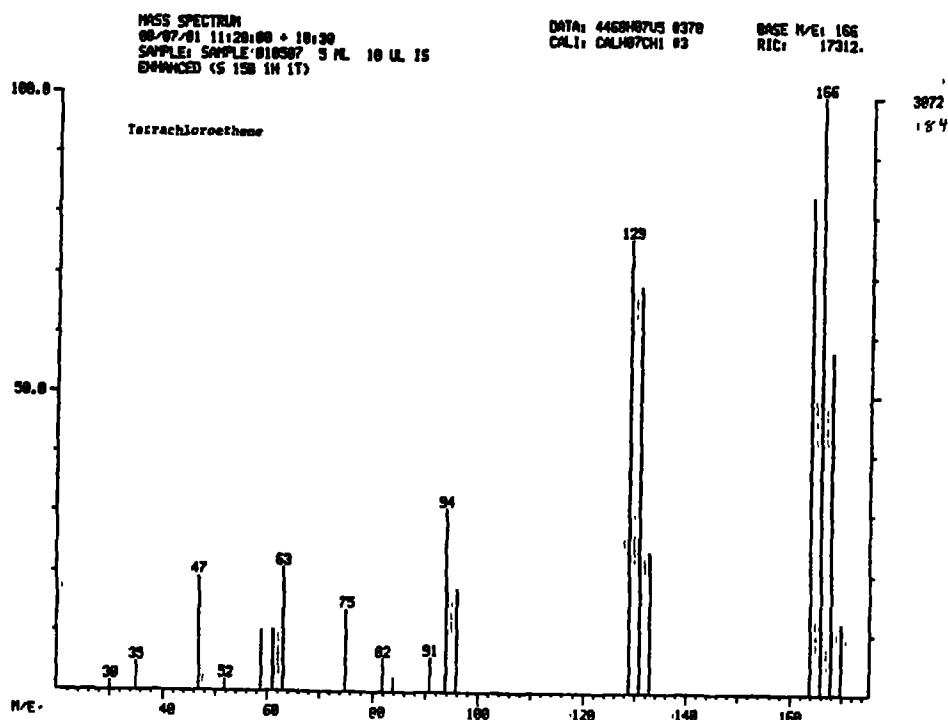


Figure 184. Mass spectrum of tetrachloroethene in sample 810507.

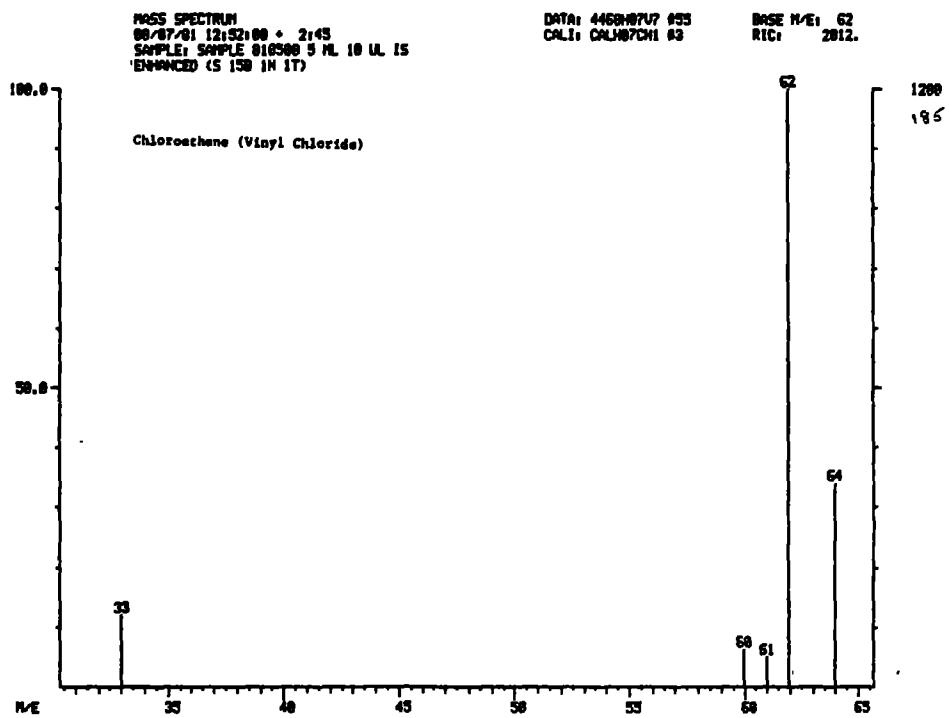


Figure 185. Mass spectrum of chloroethene (vinyl chloride) in sample 810508.

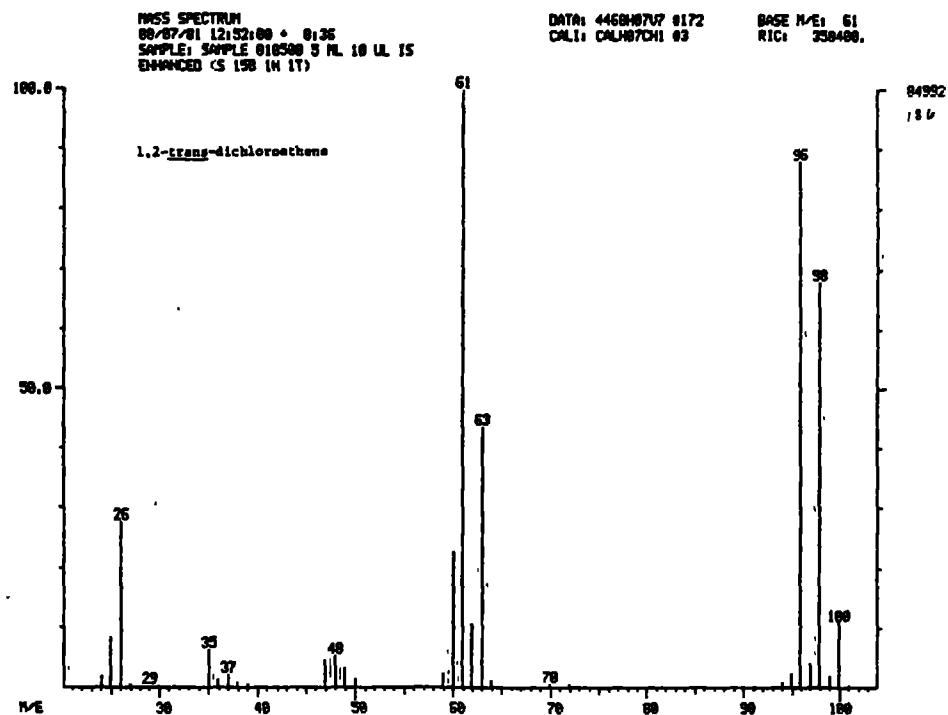


Figure 186. Mass spectrum of 1,2-trans-dichloroethene in sample 810508.

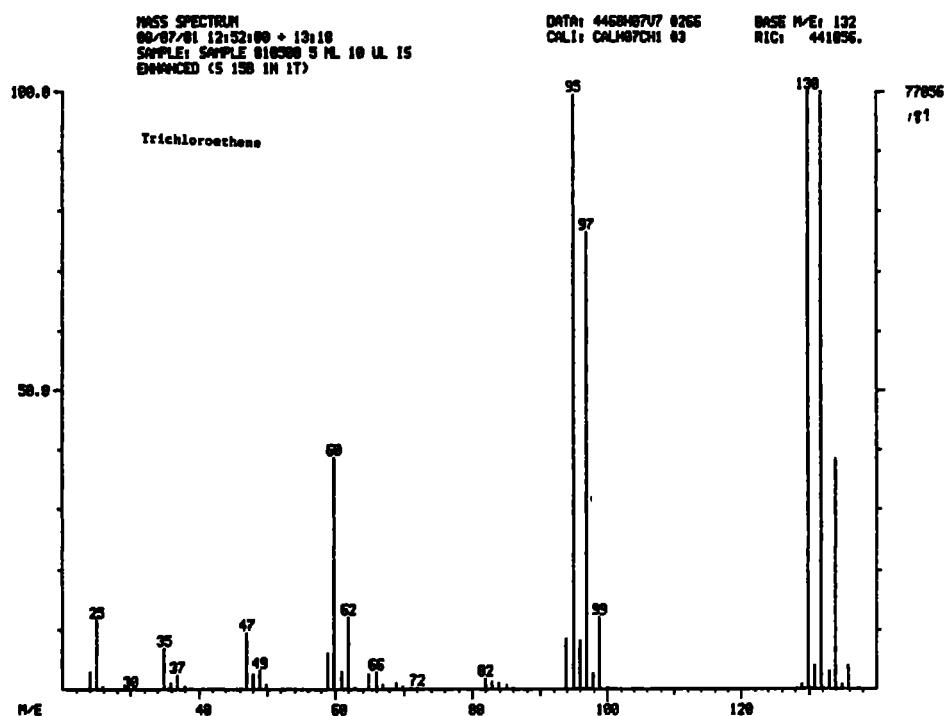


Figure 187. Mass spectrum of trichloroethene in sample 810508.

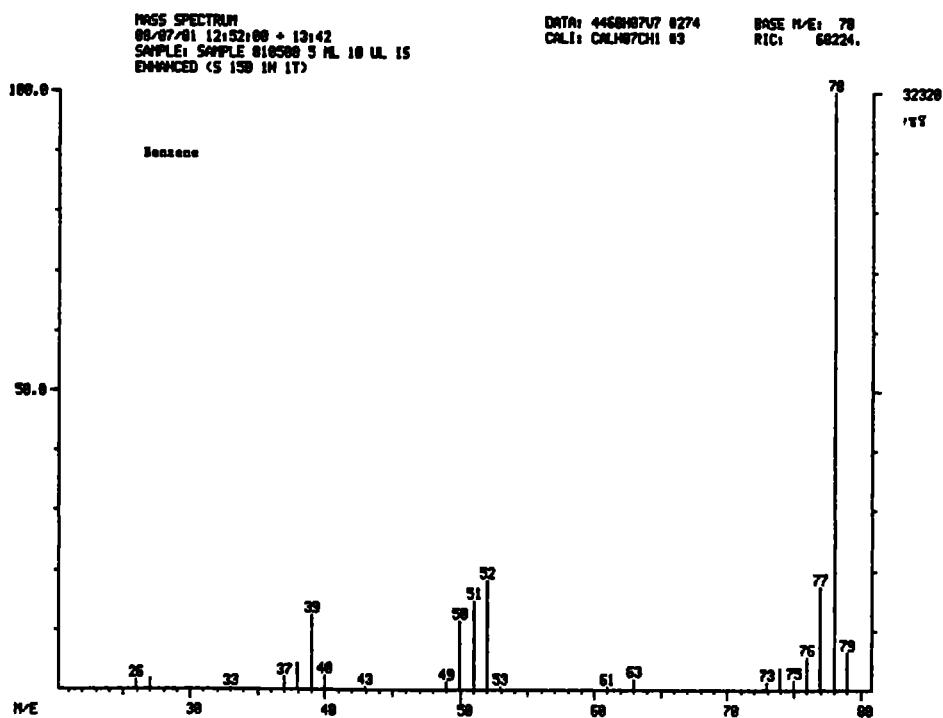


Figure 188. Mass spectrum of benzene in sample 810508.

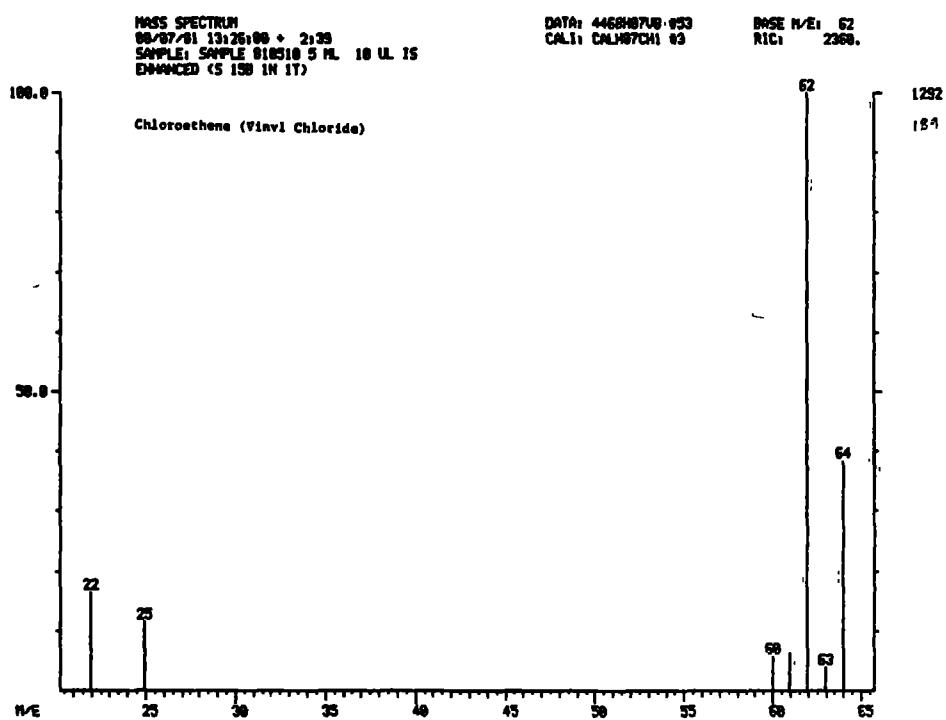


Figure 189. Mass spectrum of chloroethene (vinyl chloride) in sample 810510.

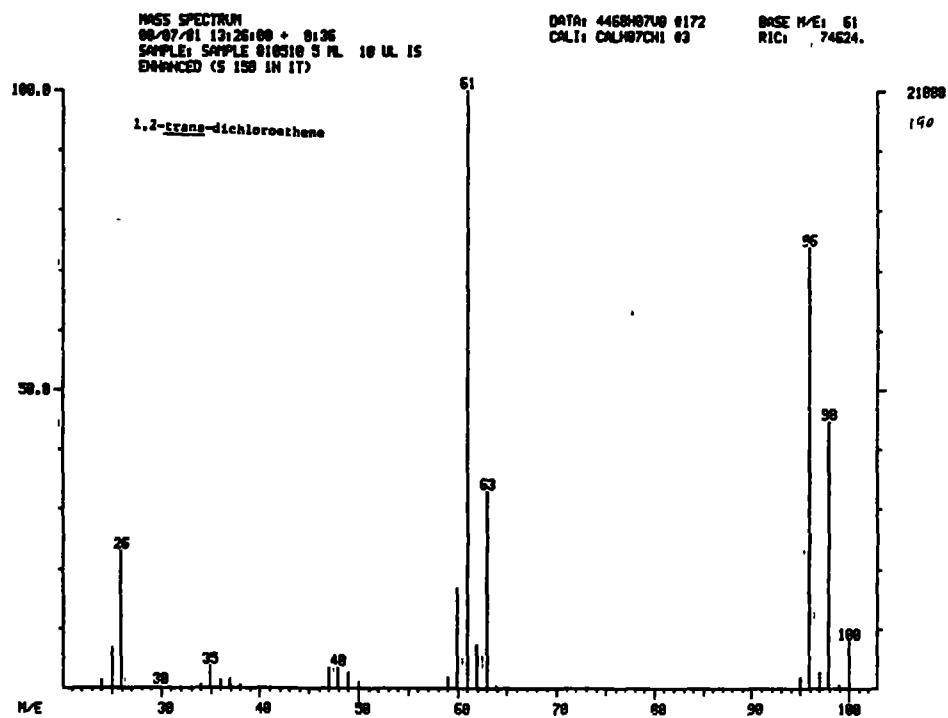


Figure 190. Mass spectrum of 1,2-trans-dichloroethene in sample 810510.

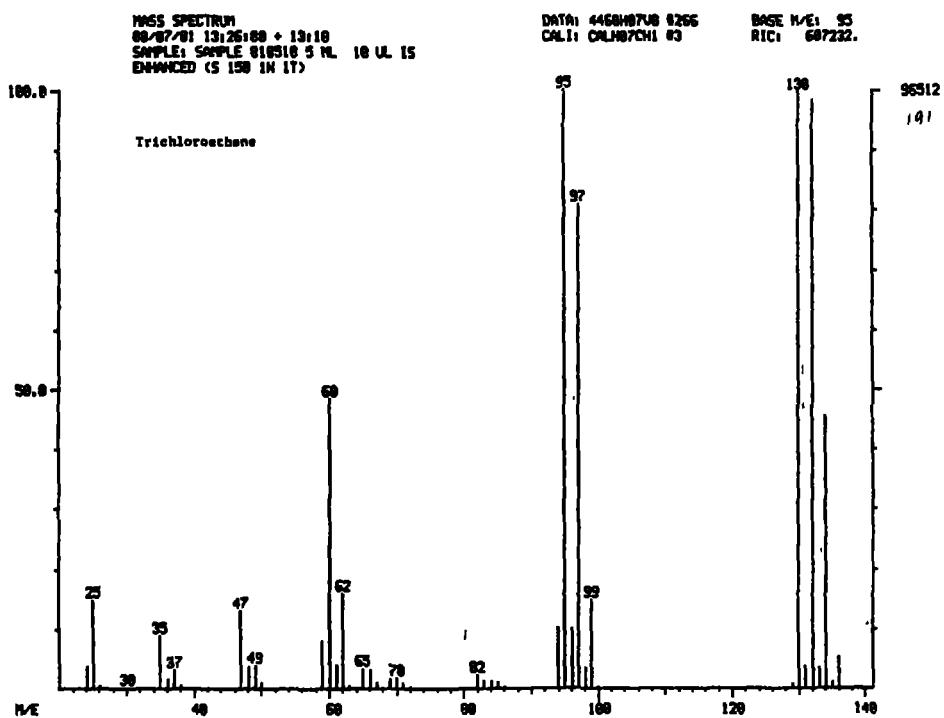


Figure 191. Mass spectrum of trichloroethene in sample 810510.

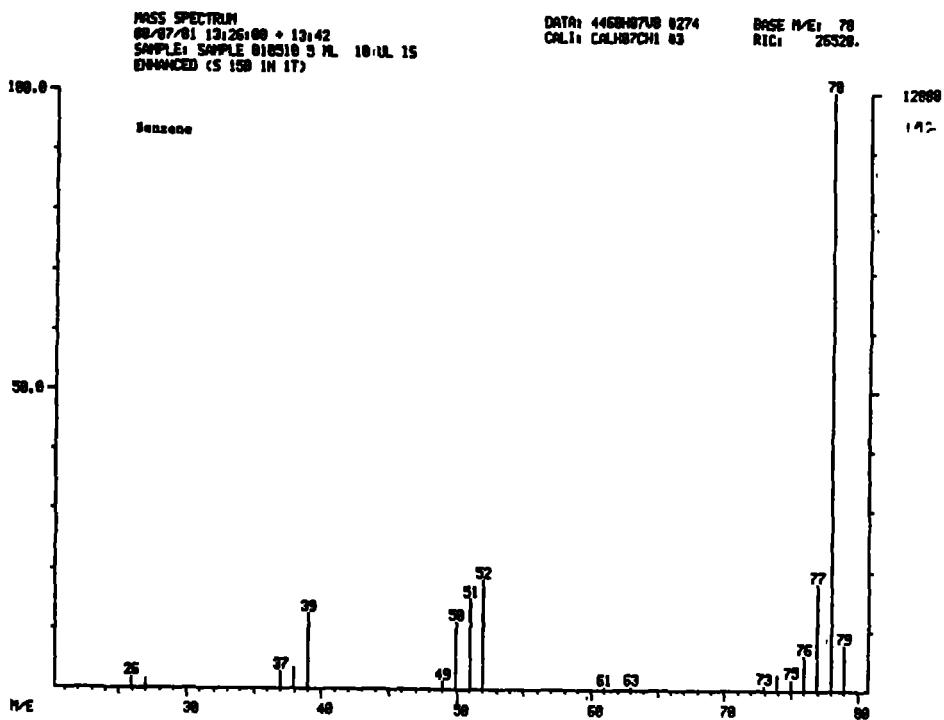


Figure 192. Mass spectrum of benzene in sample 810510.

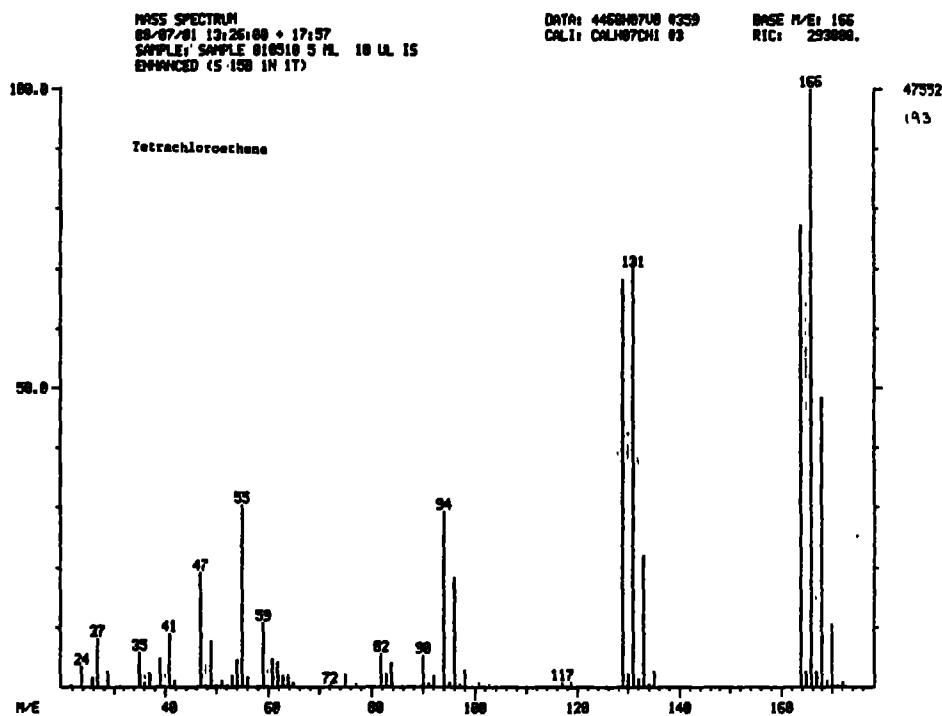


Figure 193. Mass spectrum of tetrachloroethene in sample 810510.

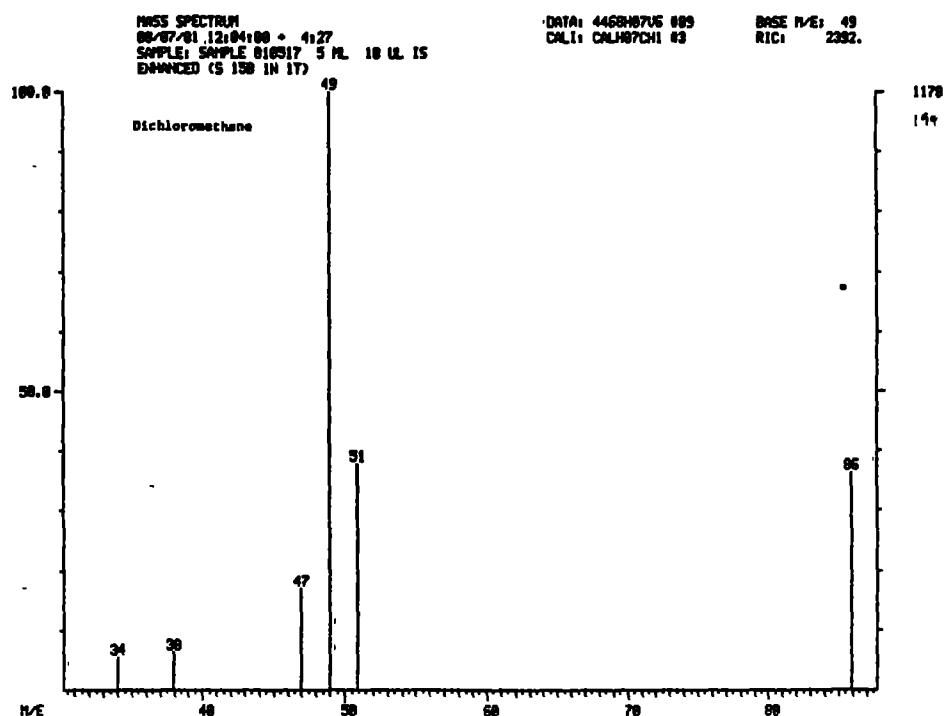


Figure 194. Mass spectrum of dichloromethane in sample 810517.

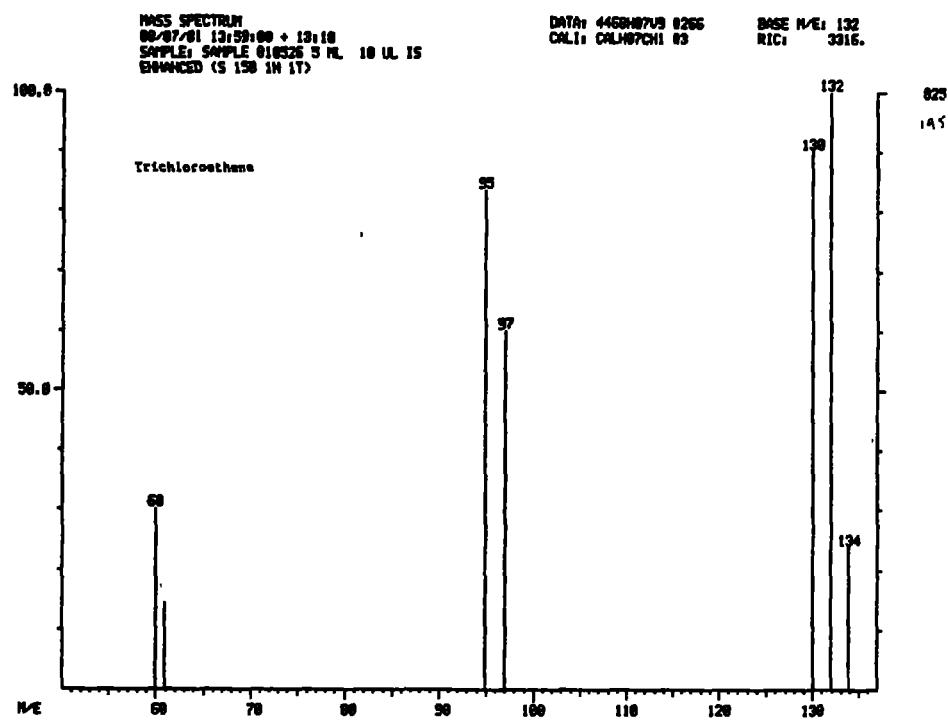


Figure 195. Mass spectrum of trichloroethene in sample 810526.

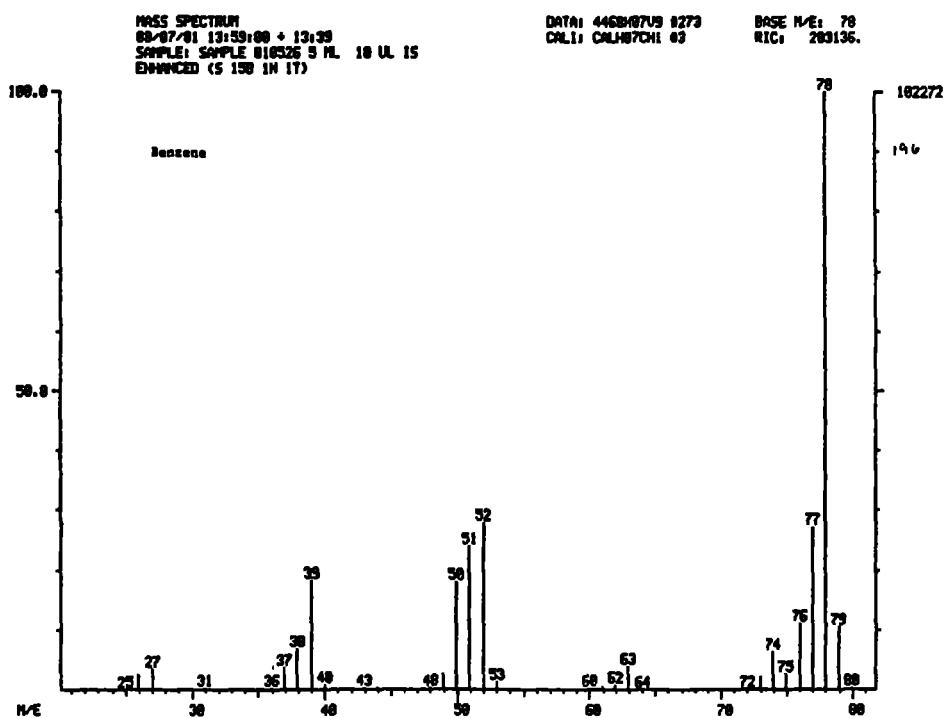


Figure 196. Mass spectrum of benzene in sample 810526.

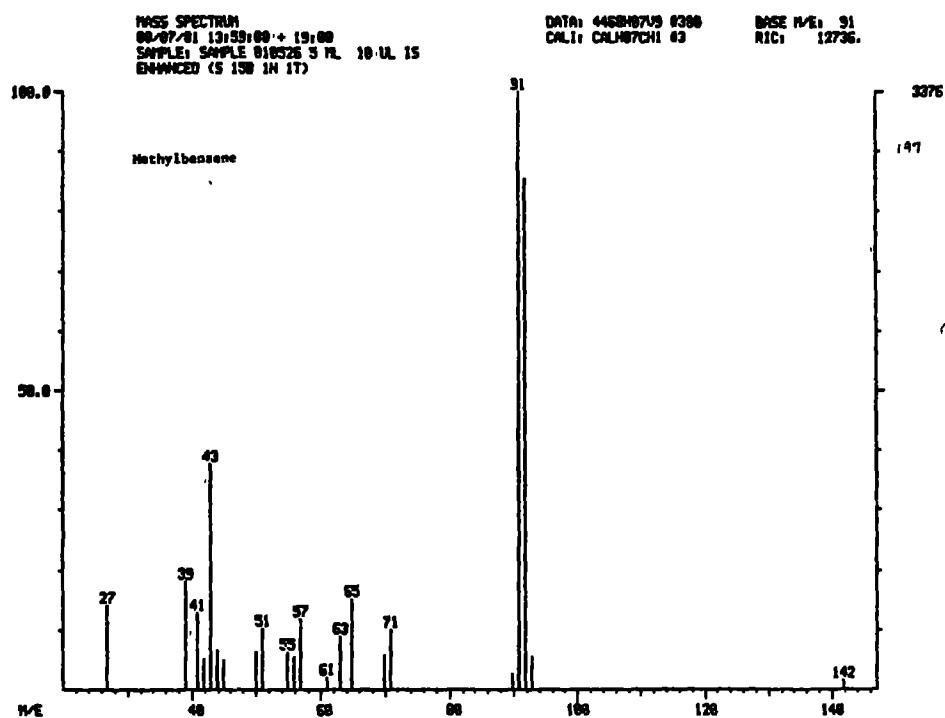


Figure 197. Mass spectrum of methylbenzene in sample 810526.

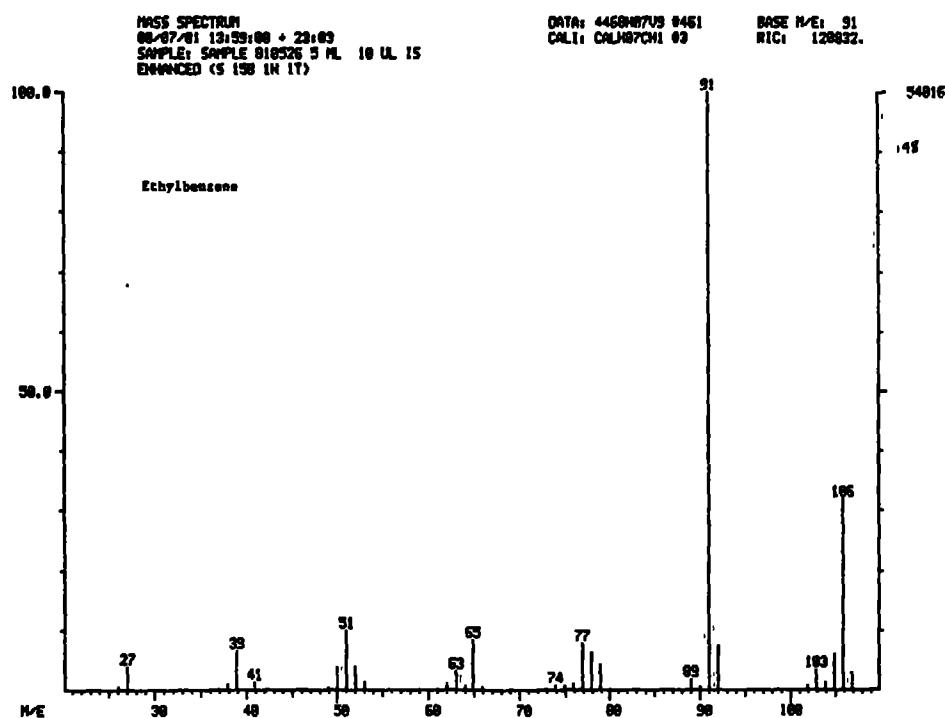


Figure 198. Mass spectrum of ethylbenzene in sample 810526.

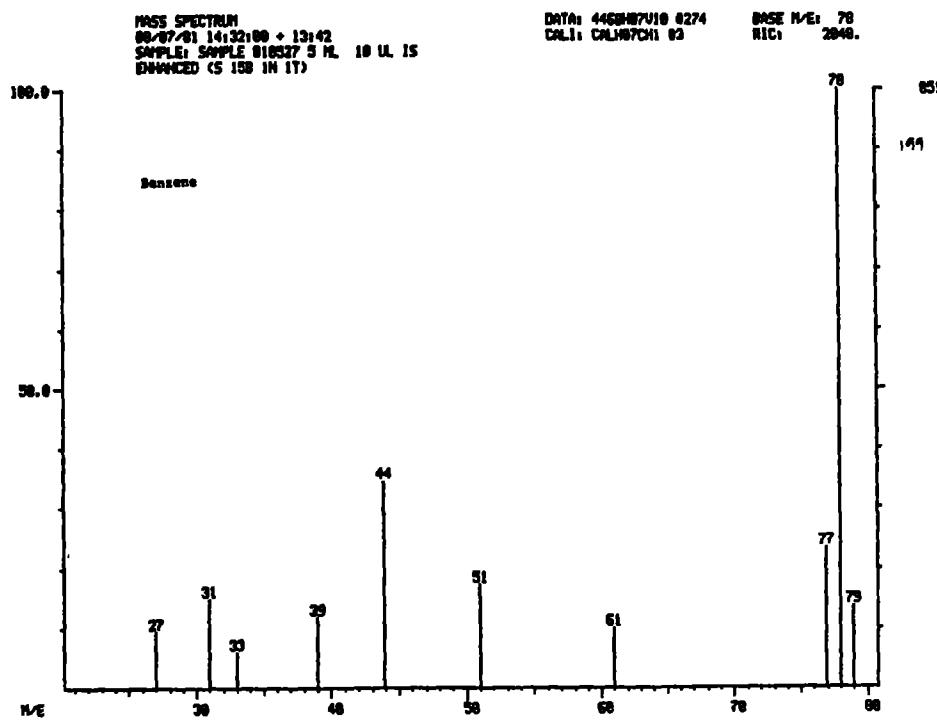


Figure 199. Mass spectrum of benzene in sample 810527.

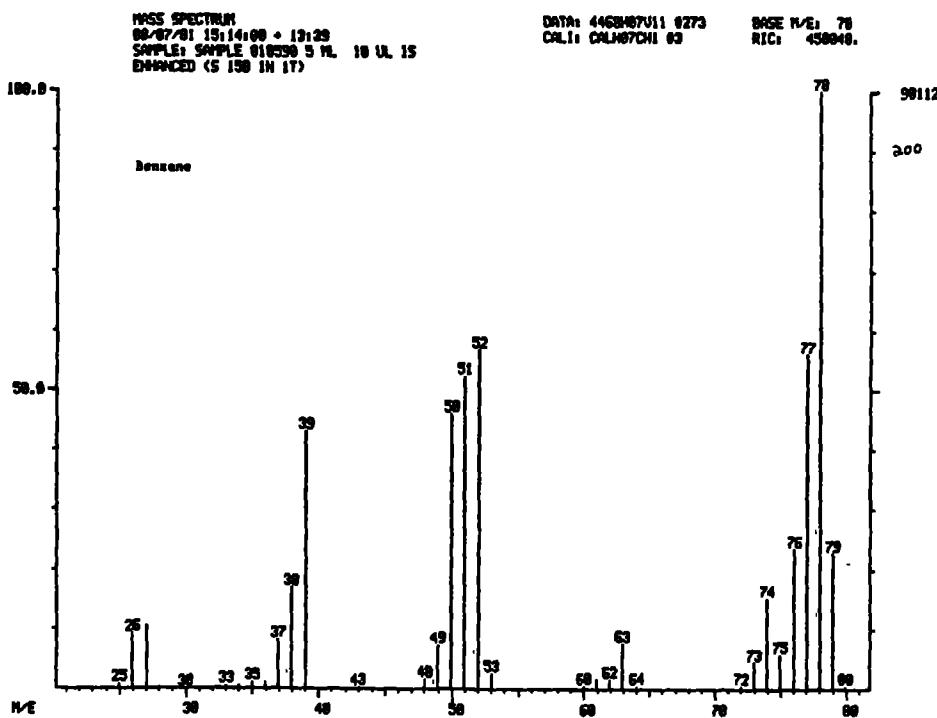


Figure 200. Mass spectrum of benzene in sample 810590.

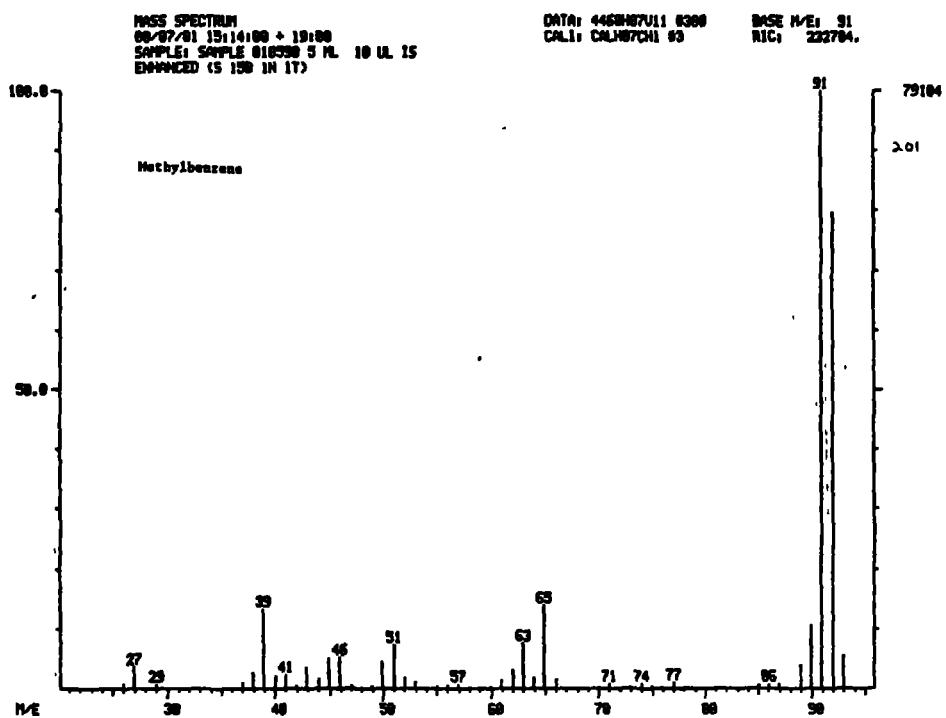


Figure 201. Mass spectrum of methylbenzene in sample 810590.

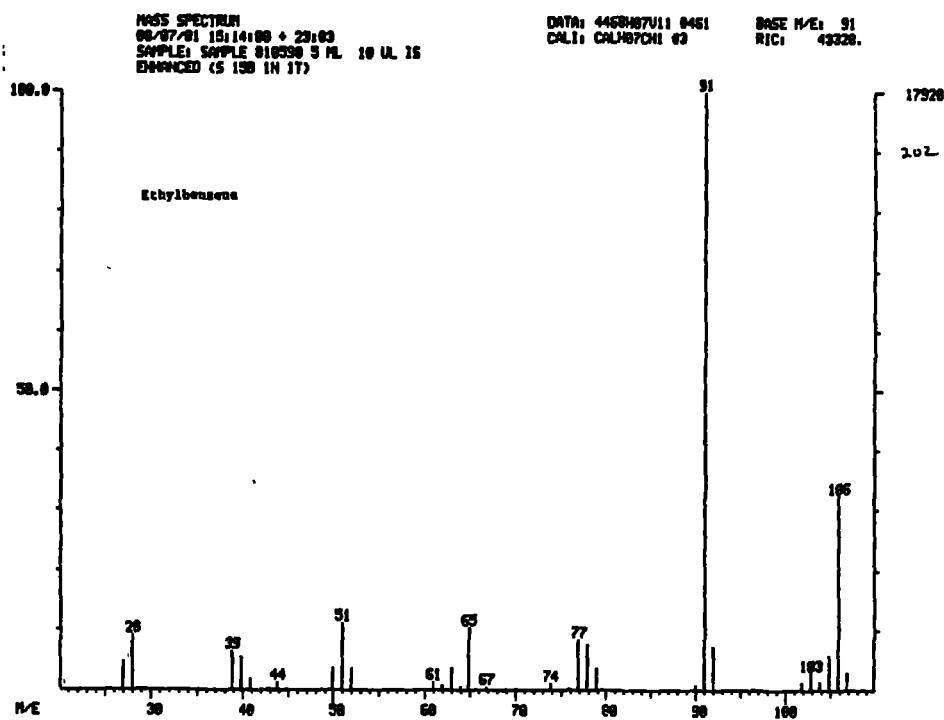


Figure 202. Mass spectrum of ethylbenzene in sample 810590.

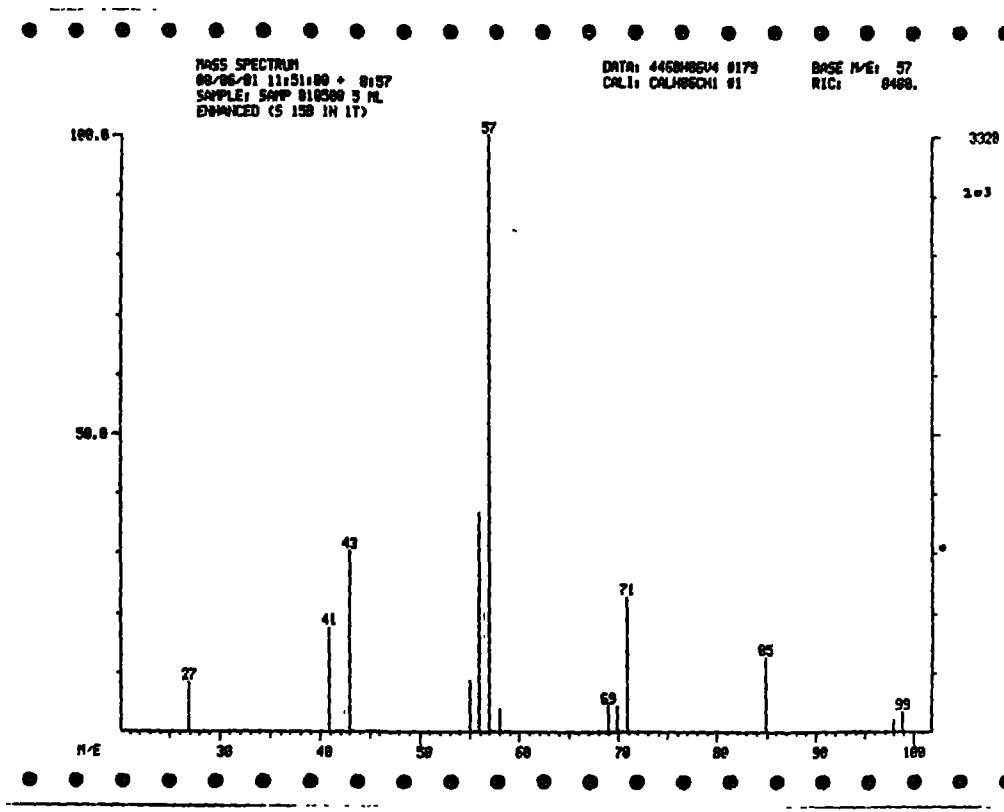


Figure 203. Mass spectrum of 3-methyloctane or similar alkane in sample 810508.

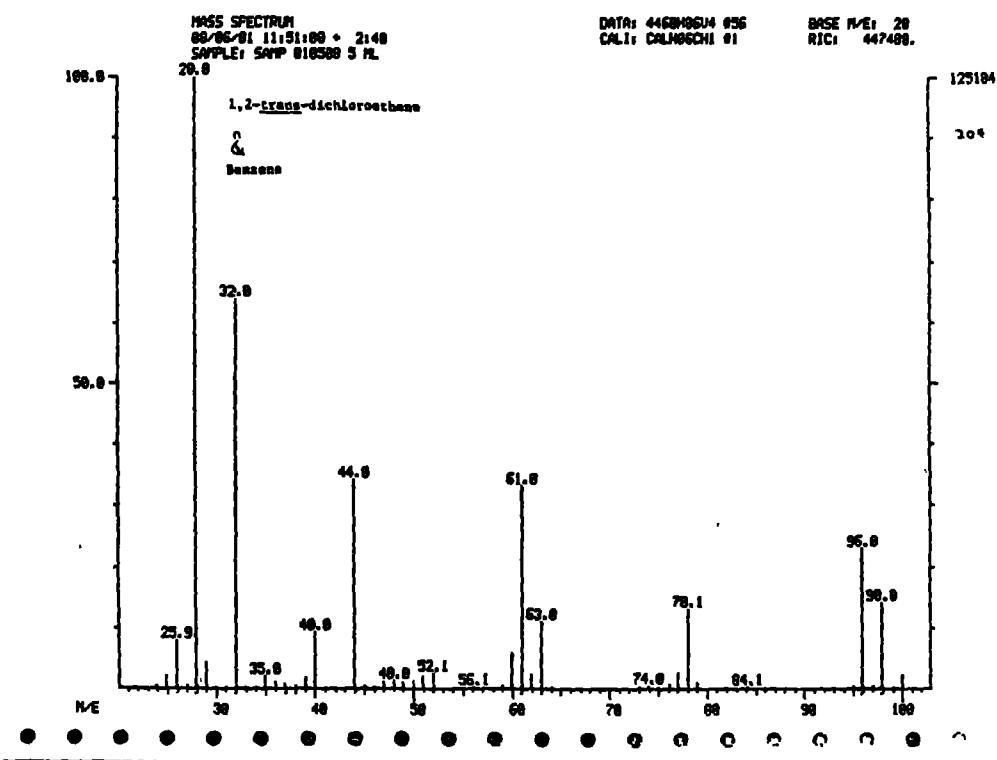
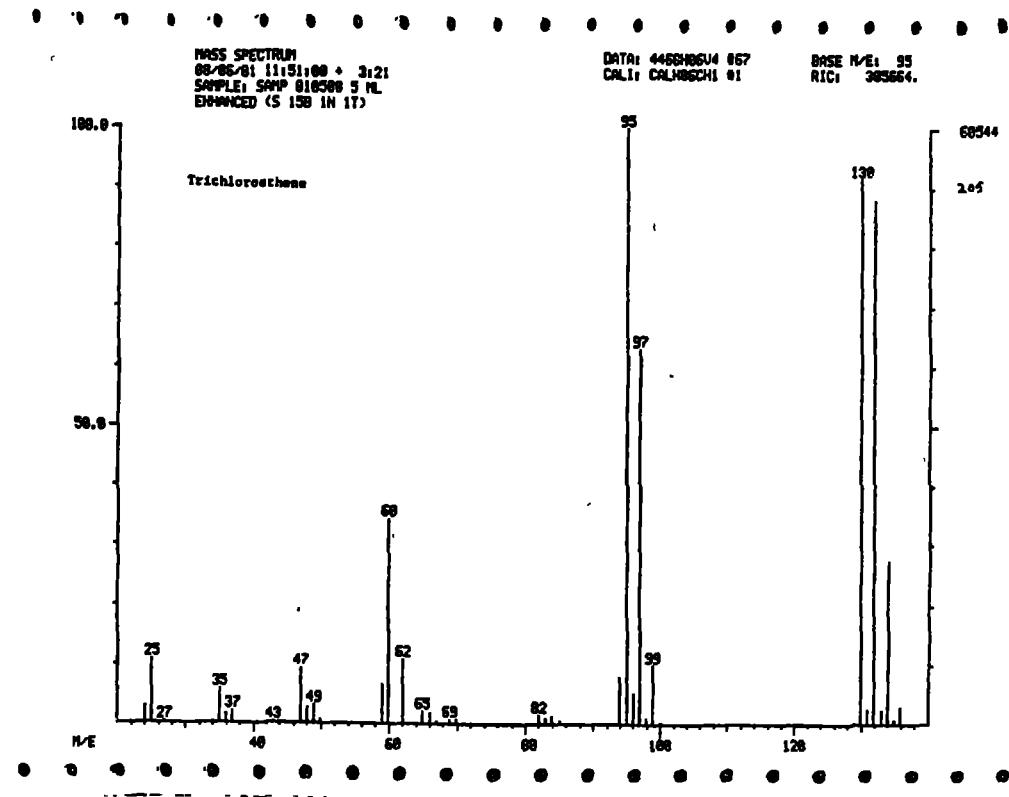


Figure 204. Mass spectrum of dichloroethene and benzene in sample 810508.



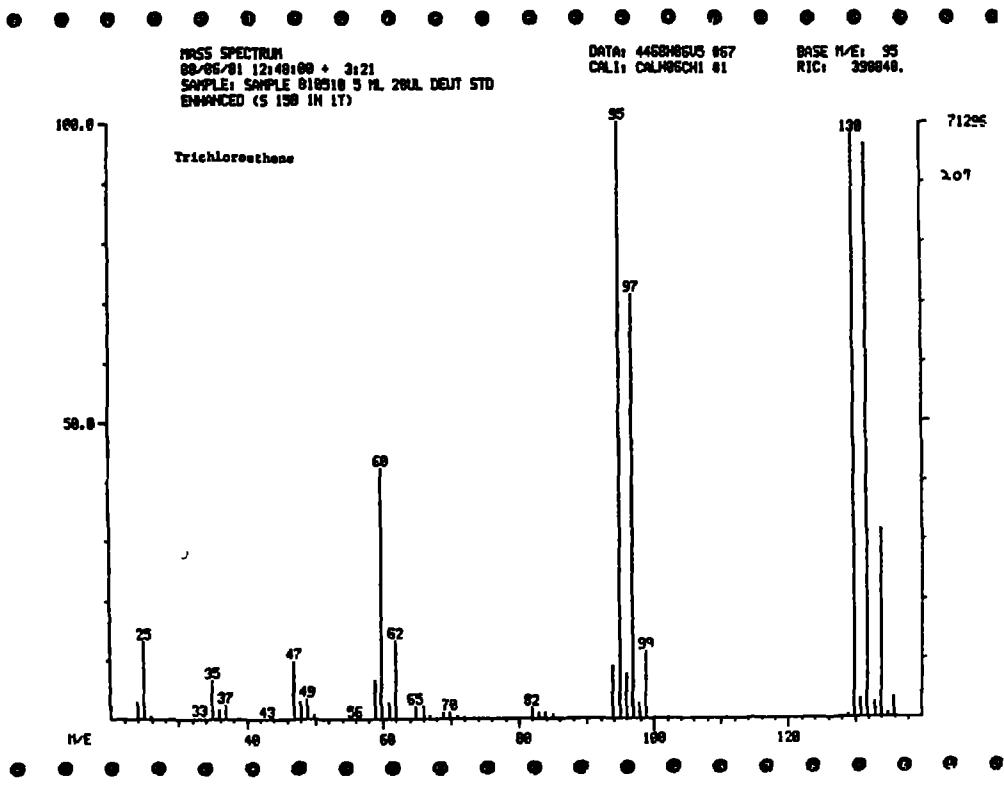


Figure 207. Mass spectrum of trichloroethene in sample 810510.

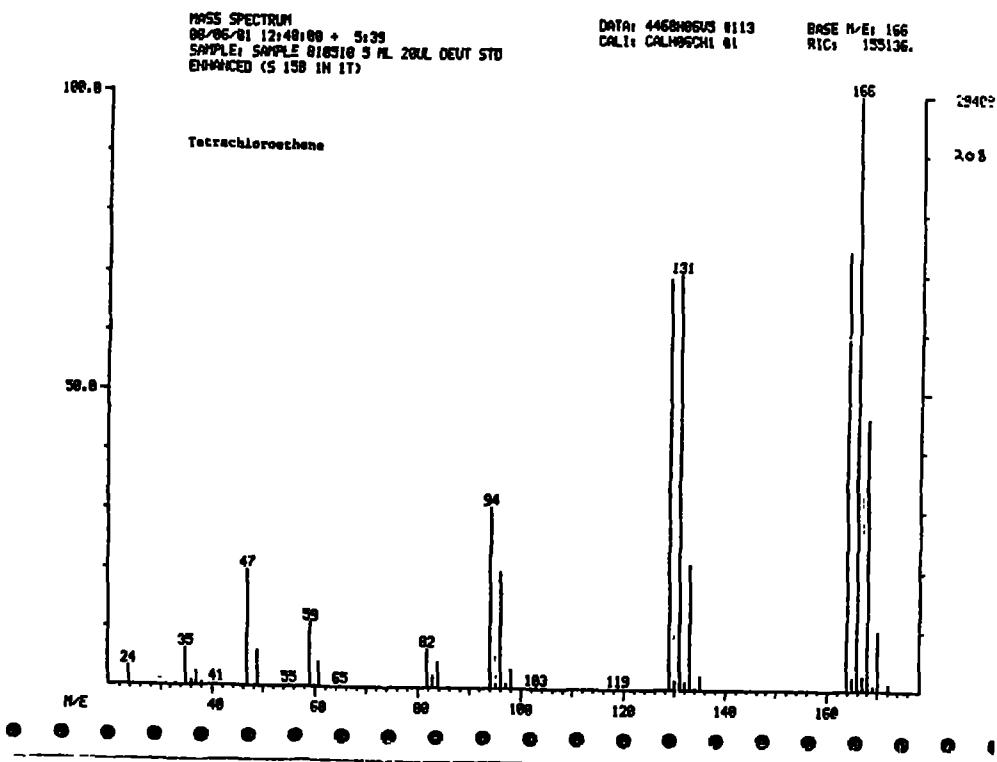


Figure 208. Mass spectrum of tetrachloroethene in sample 810510.

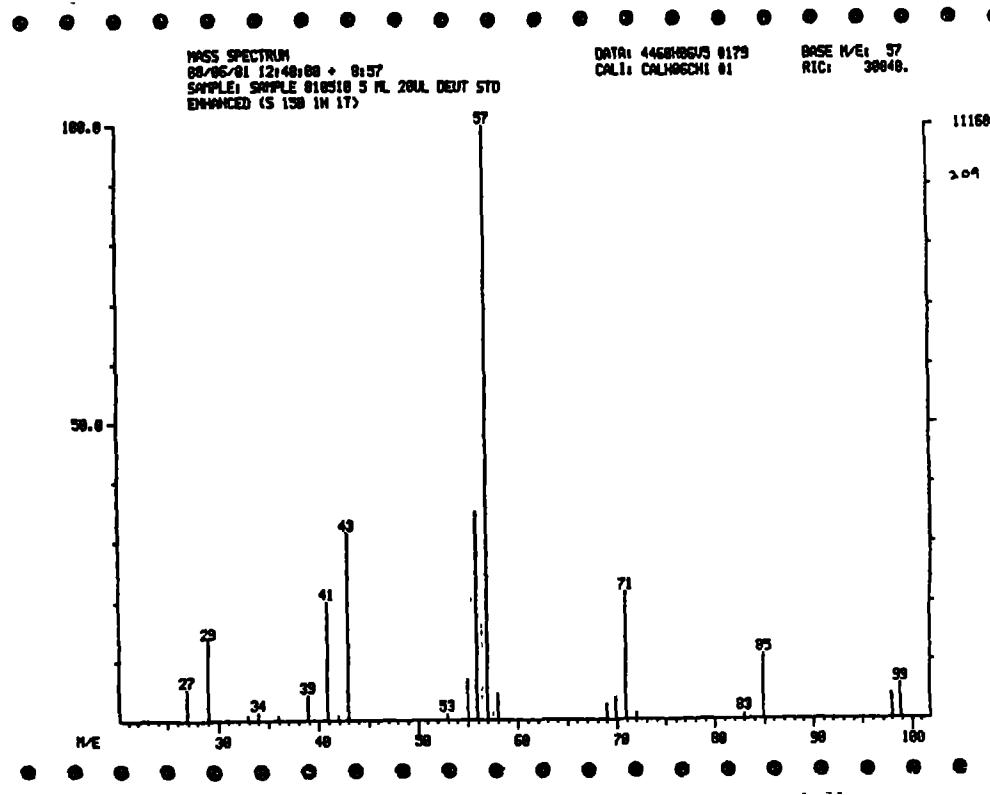


Figure 209. Mass spectrum of 3-methyloctane or similar alkane in sample 810510.

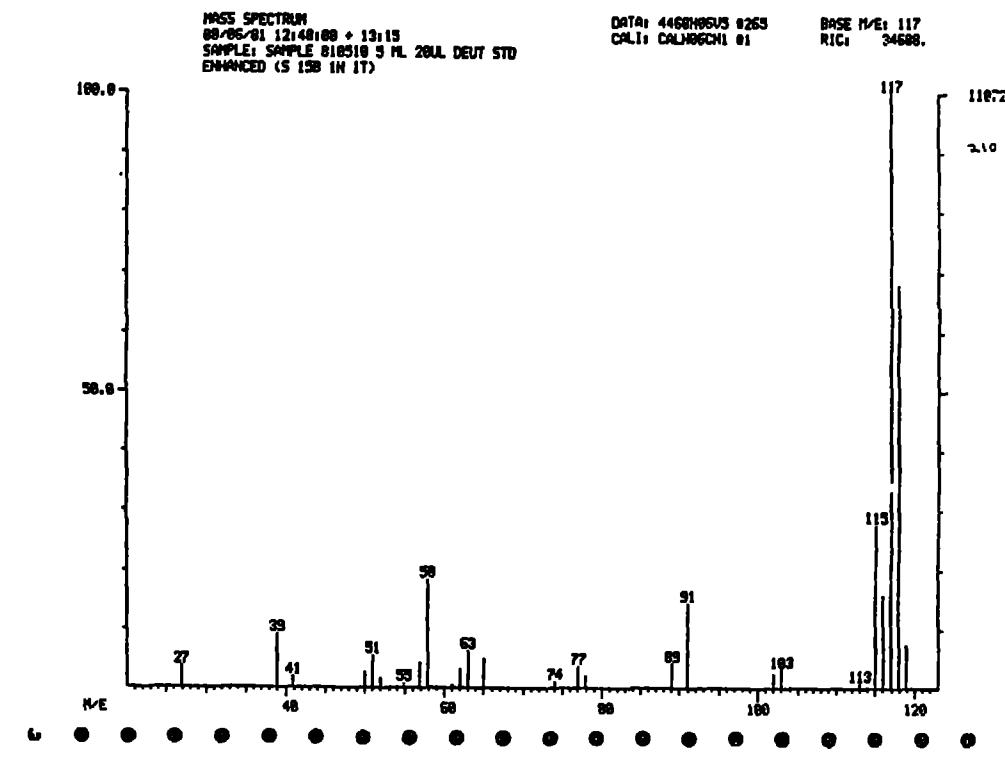


Figure 210. Mass spectrum of 2,3-dihydro-1H-indene in sample 810510.

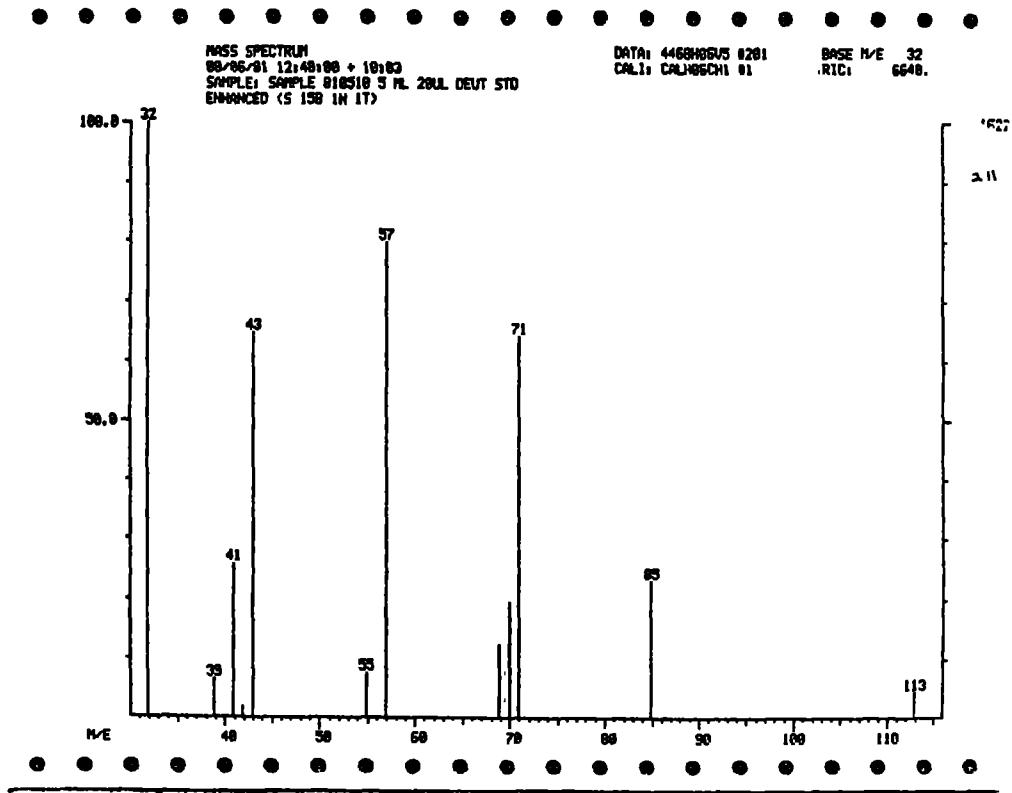


Figure 211. Mass spectrum of a branched alkane (possibly a decane) in sample 810510.

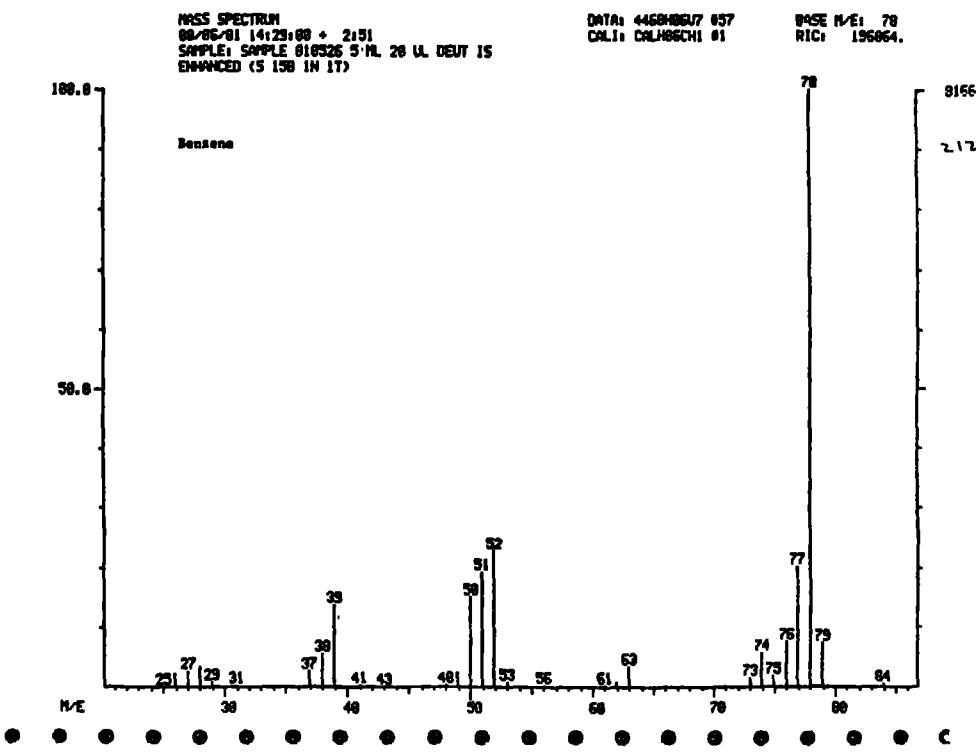


Figure 212. Mass spectrum of benzene in sample 810526.

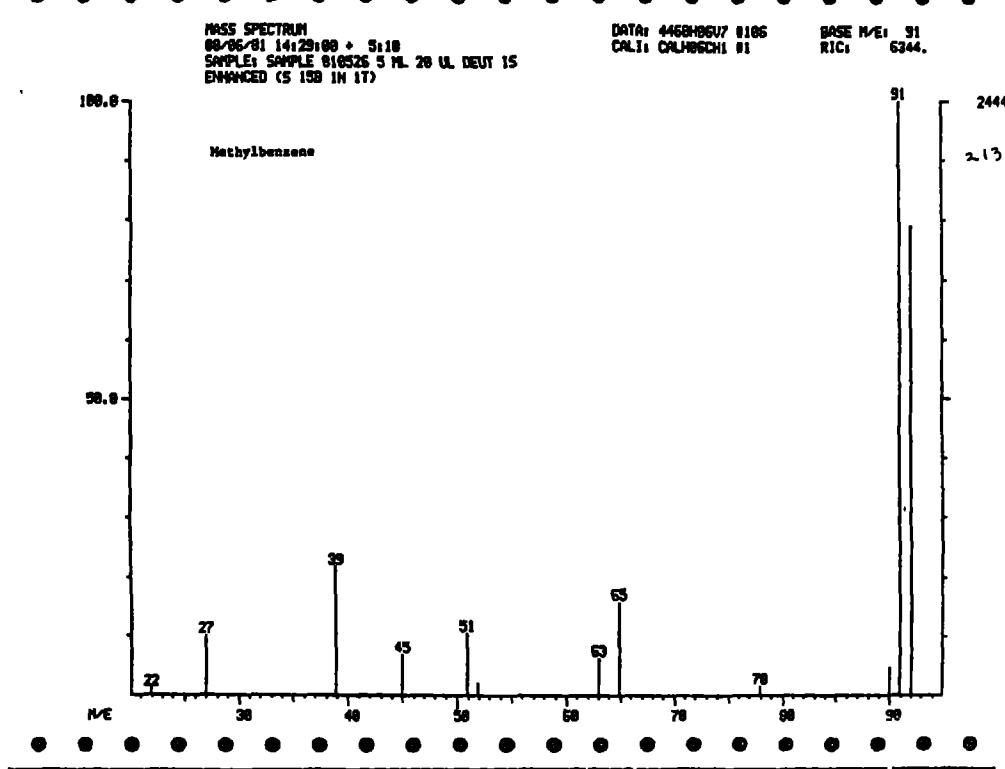


Figure 213. Mass spectrum of methylbenzene in sample 810526.

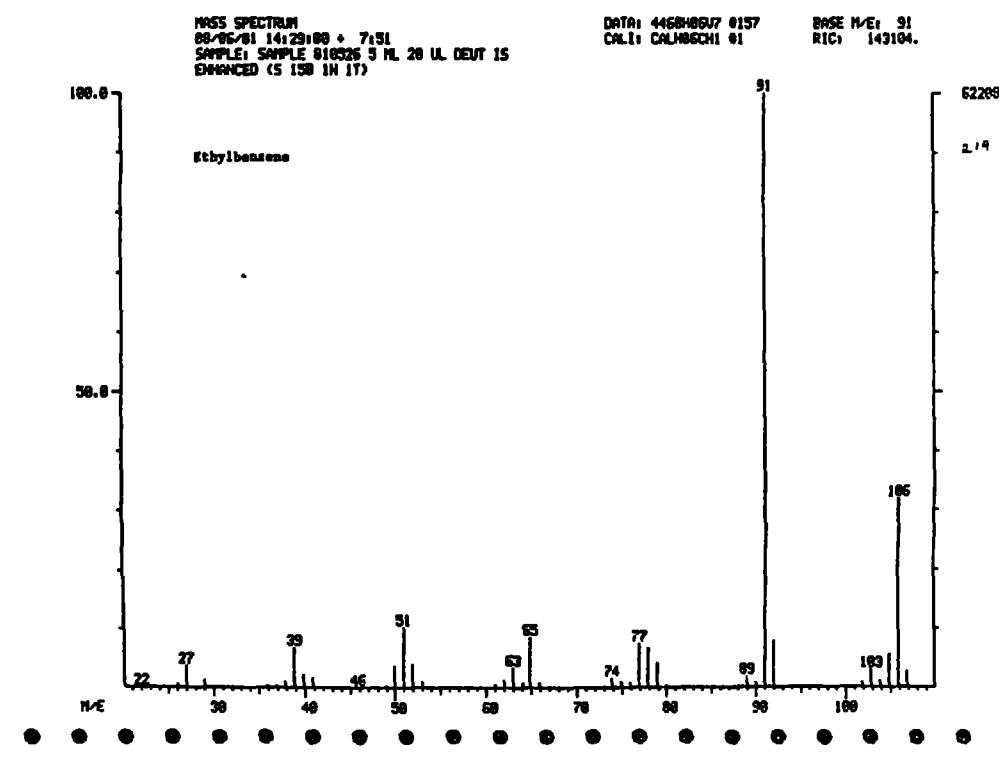


Figure 214. Mass spectrum of ethylbenzene in sample 810526.

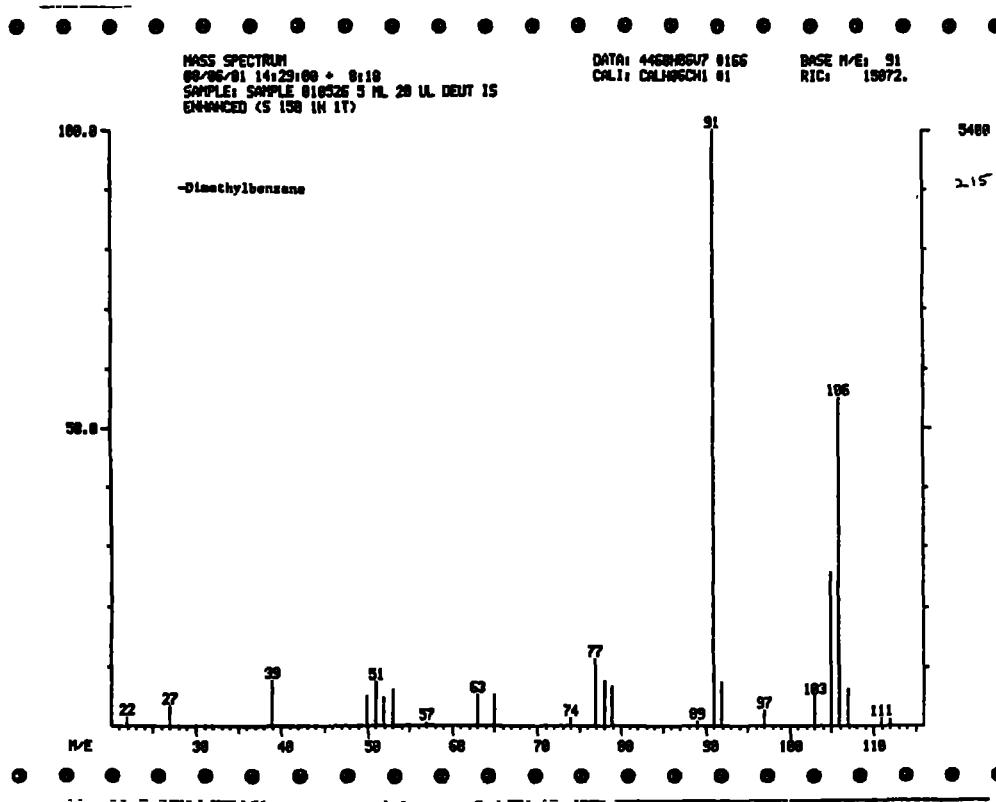


Figure 215. Mass spectrum of a dimethylbenzene in sample 810526.

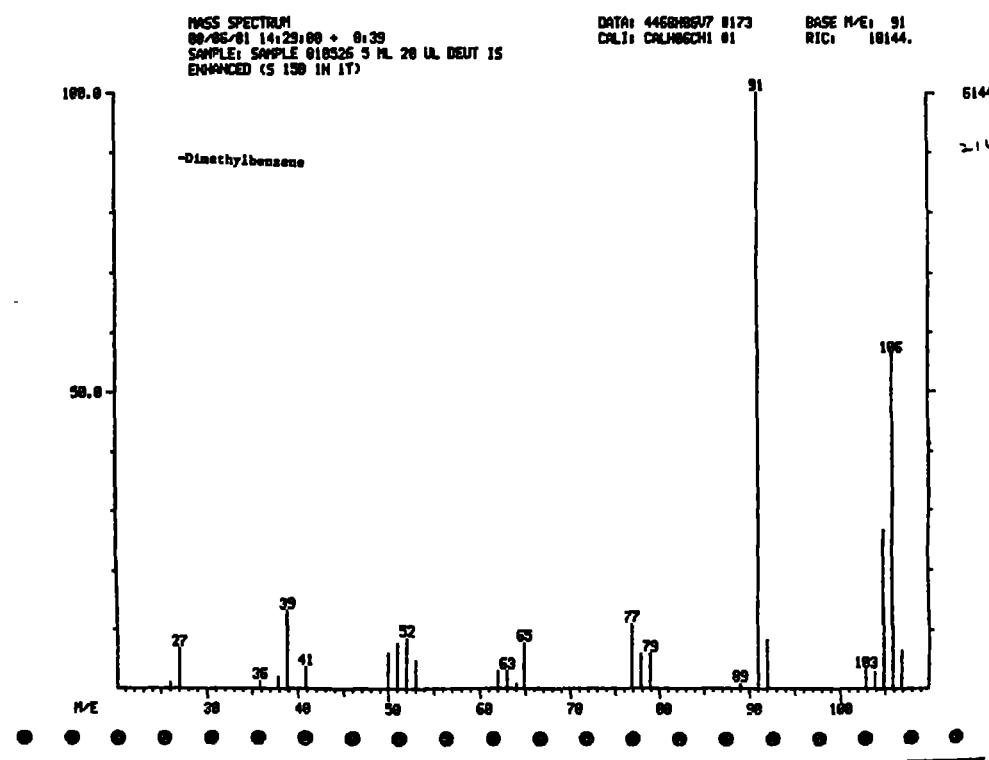


Figure 216. Mass spectrum of a dimethylbenzene in sample 810526.

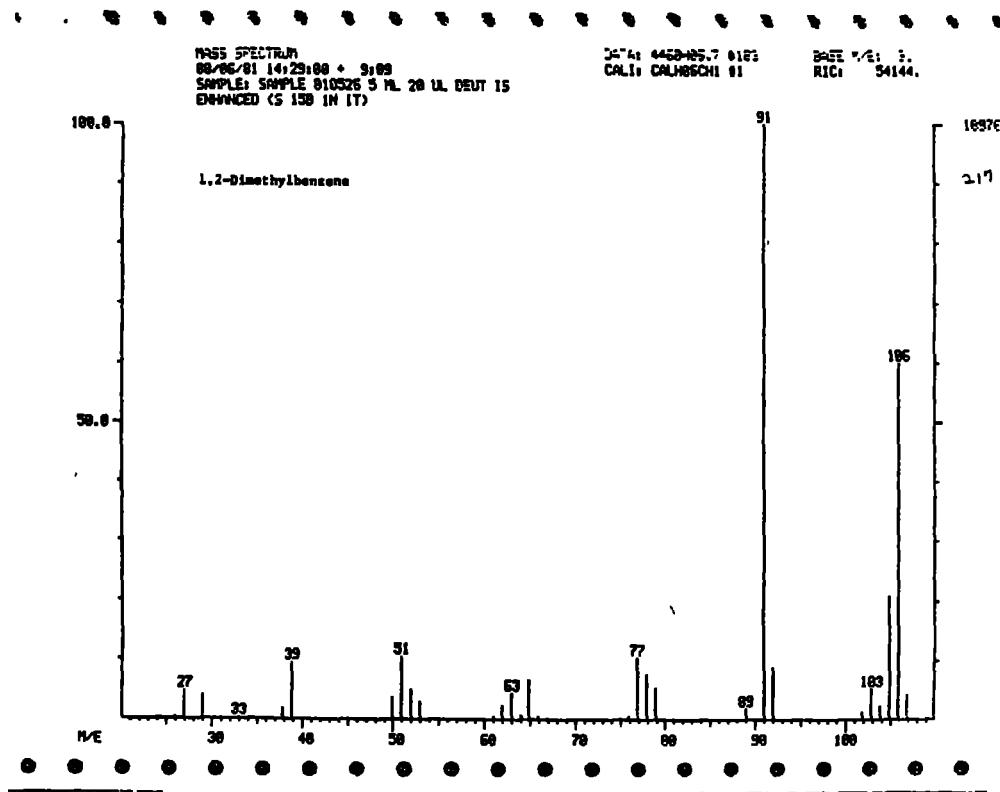


Figure 217. Mass spectrum of 1,2-dimethylbenzene in sample 810526.

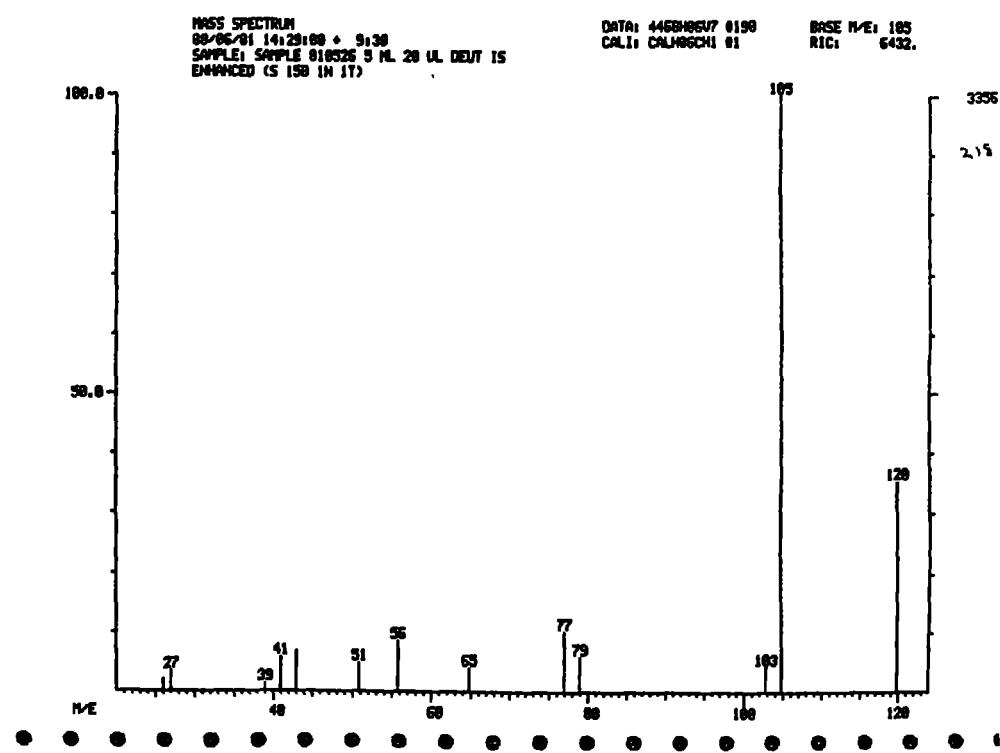


Figure 218. Mass spectrum of isopropylbenzene in sample 810526.

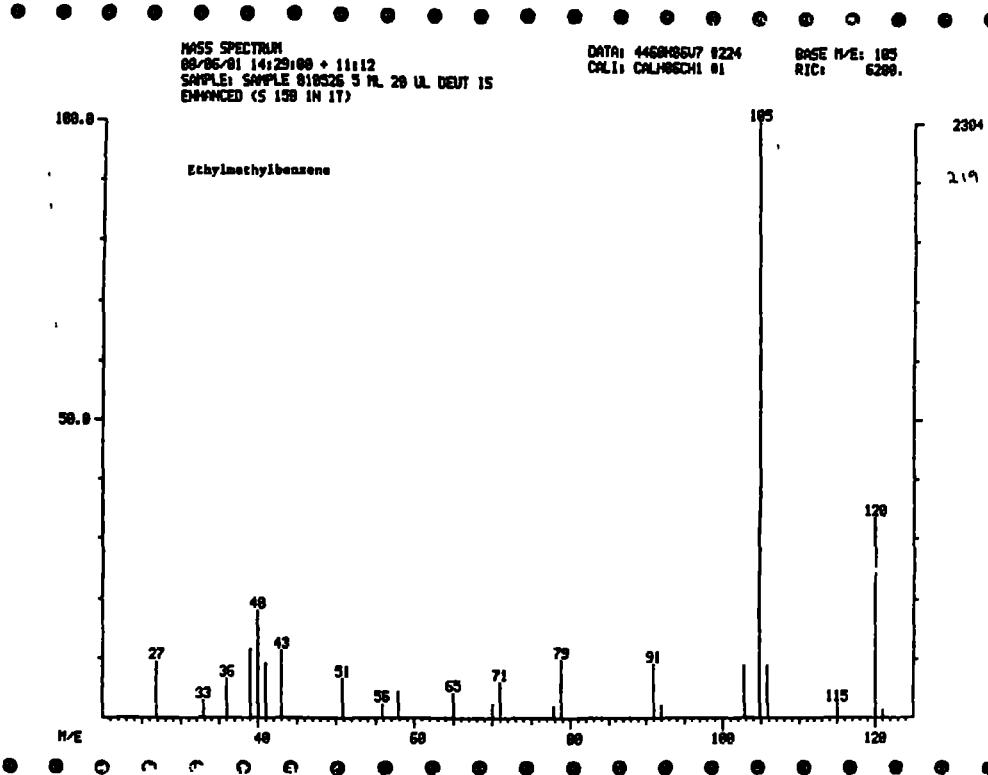


Figure 219. Mass spectrum of an ethylmethylbenzene in sample 810526.

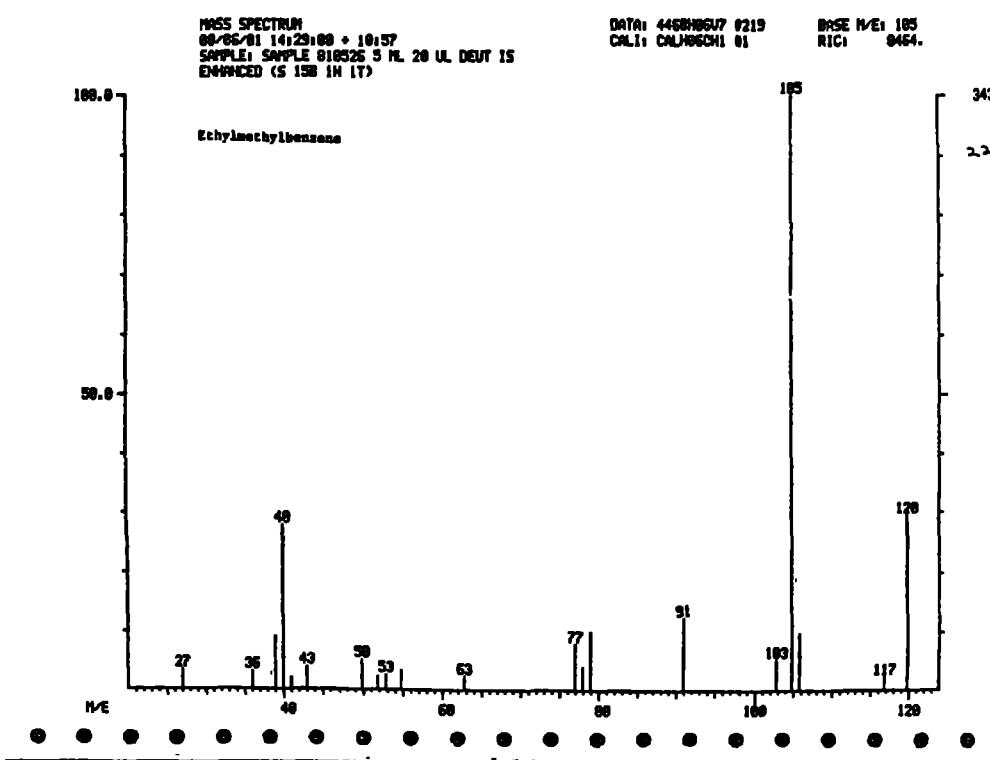


Figure 220. Mass spectrum of an ethylmethylbenzene in sample 810526.

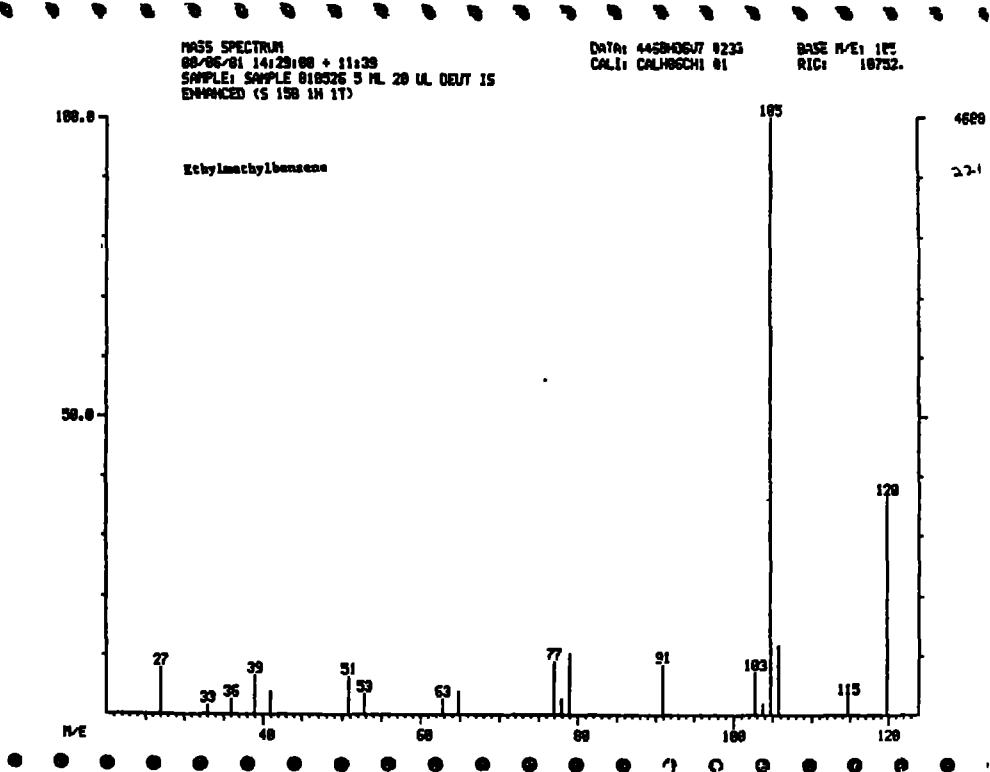


Figure 221. Mass spectrum of an ethylmethylbenzene in sample 810526.

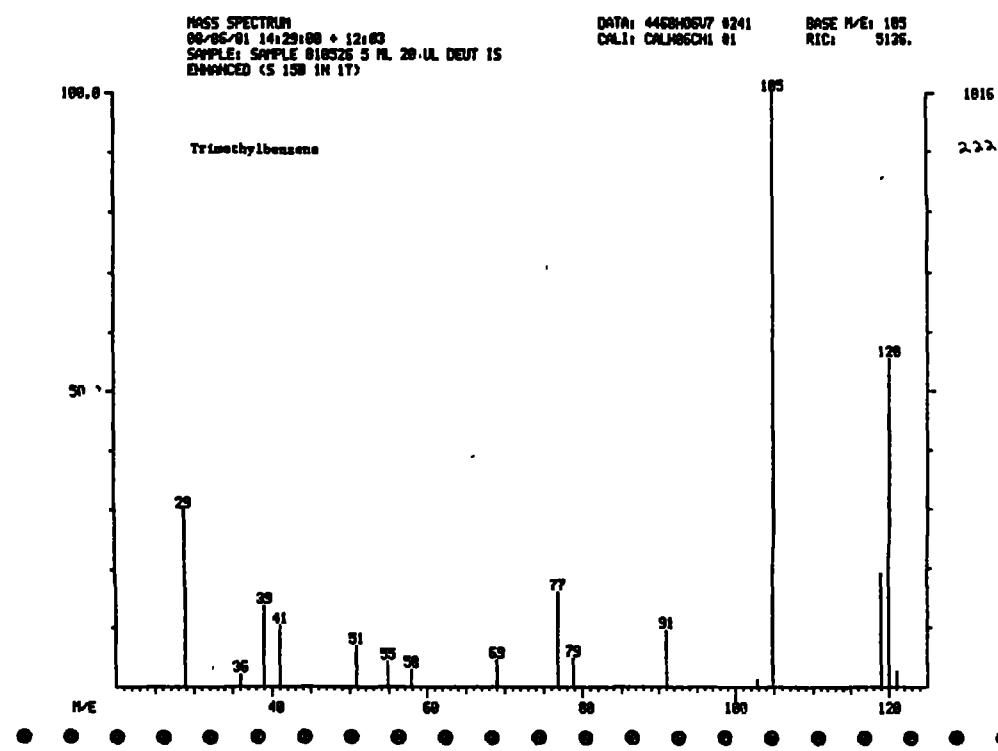


Figure 222. Mass spectrum of a trimethylbenzene in sample 810526.

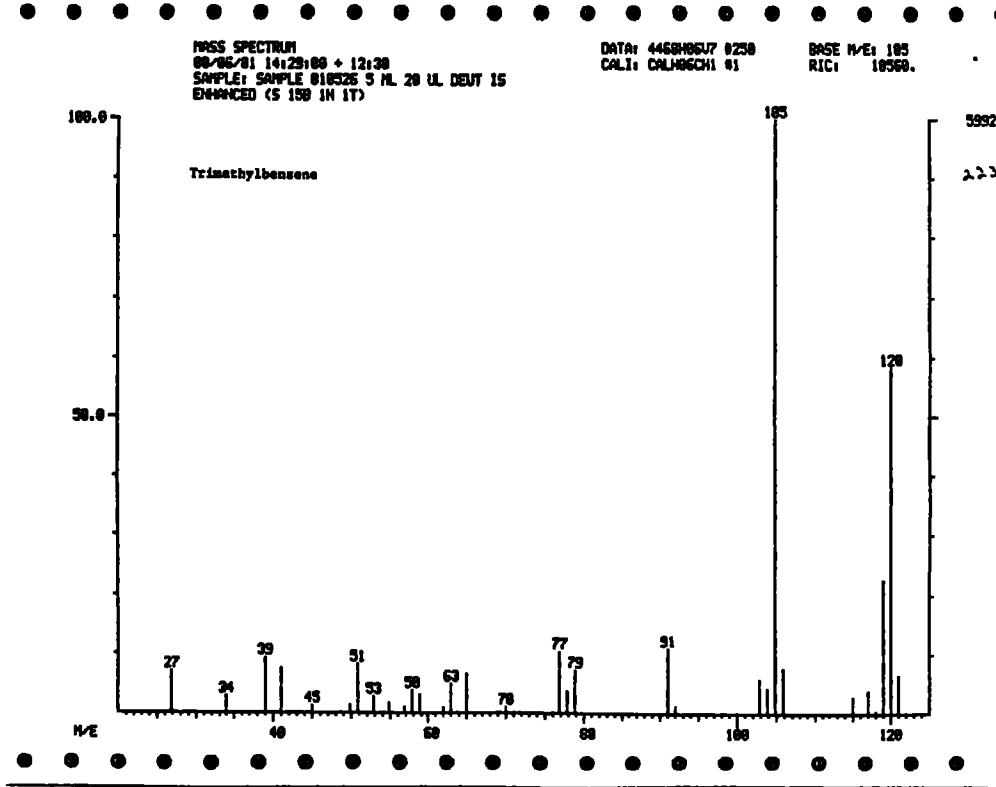


Figure 223. Mass spectrum of a trimethylbenzene in sample 810526.

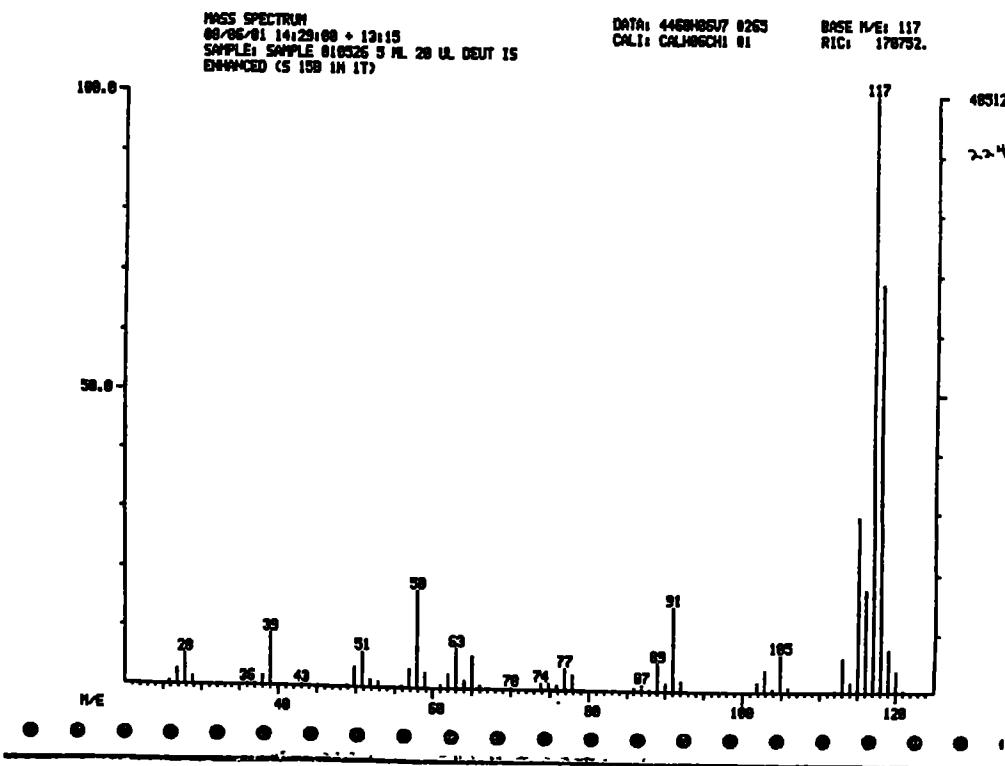


Figure 224. Mass spectrum of 2,3-dihydro-1H-indene in sample 810526.

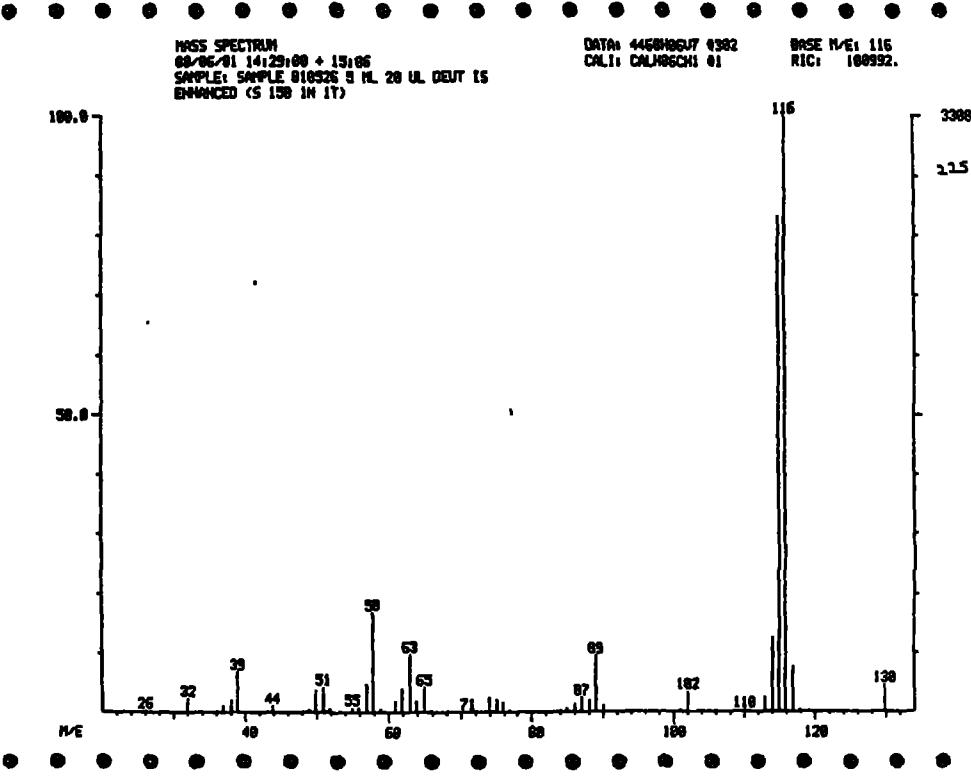


Figure 225. Mass spectrum of 1H-indene in sample 810526.

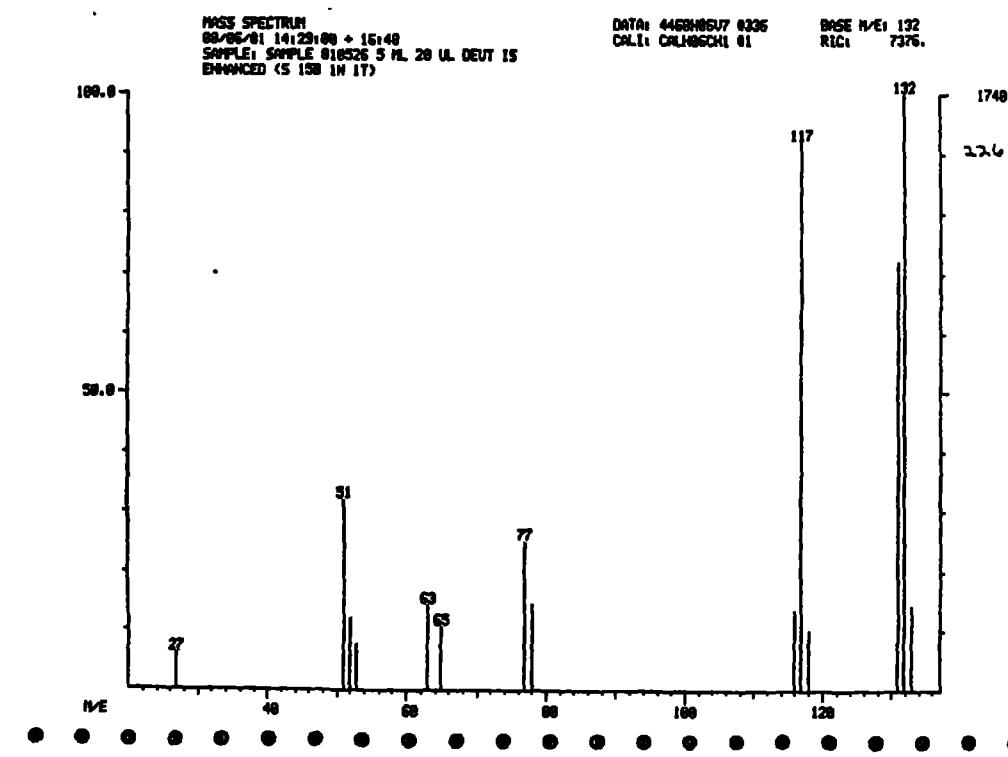


Figure 226. Mass spectrum of a methyldihydroindene in sample 810526.

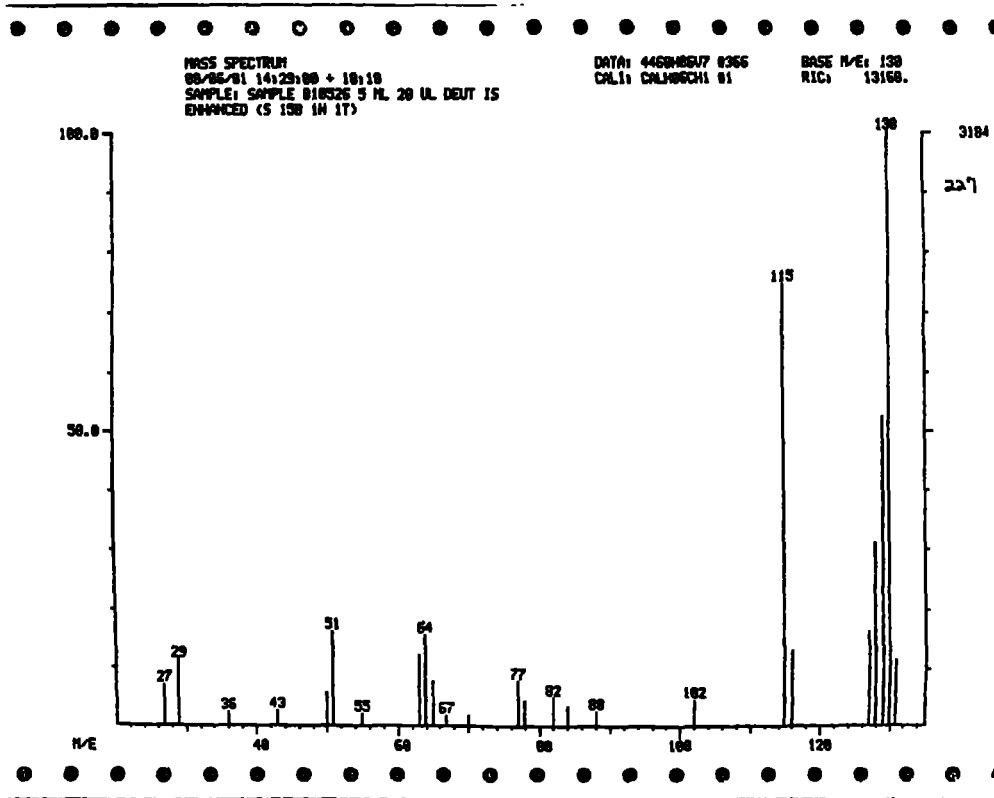


Figure 227. Mass spectrum of 1-methyl-1H-indene in sample 810526.

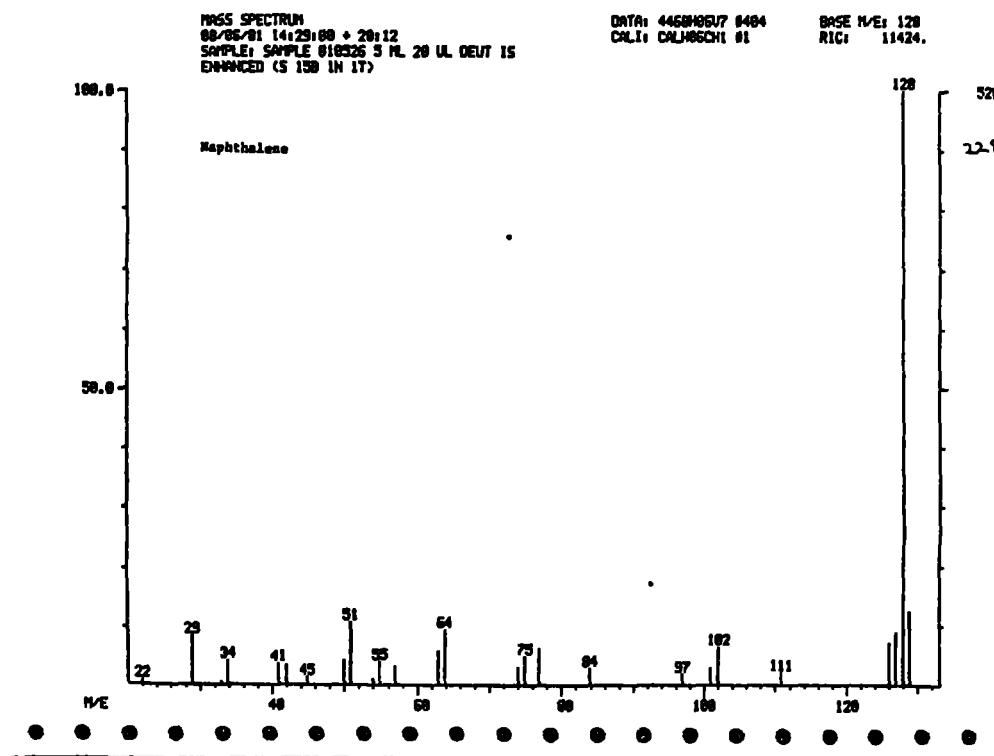


Figure 228. Mass spectrum of naphthalene in sample 810526.

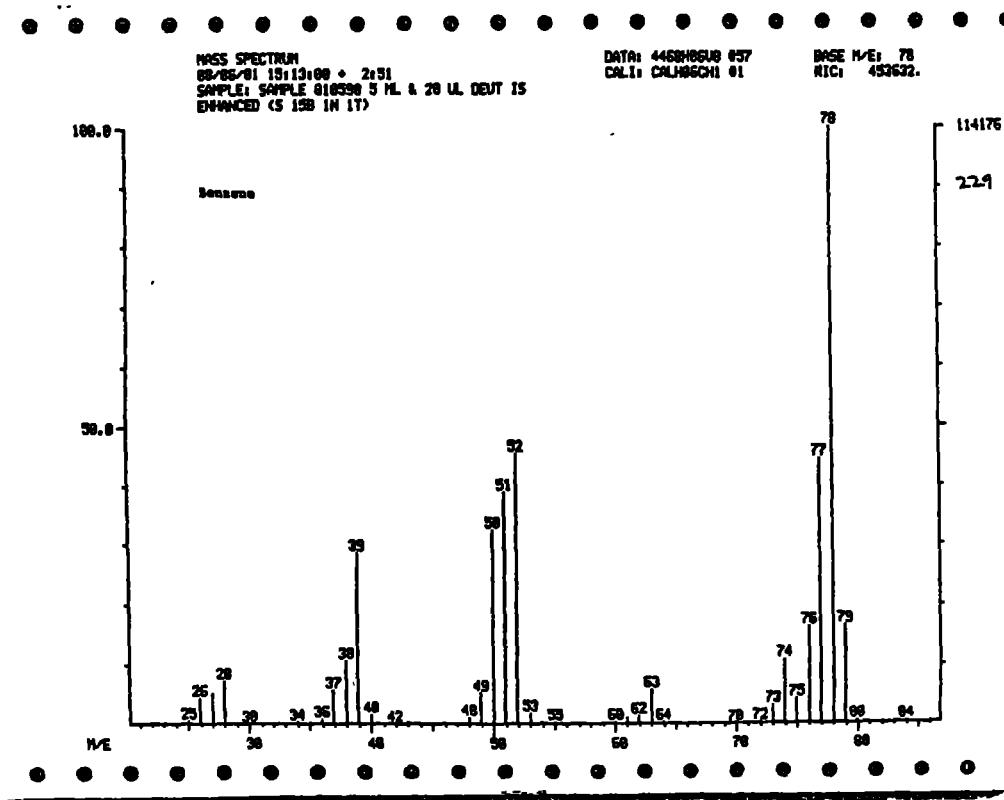


Figure 229. Mass spectrum of benzene in sample 810590.

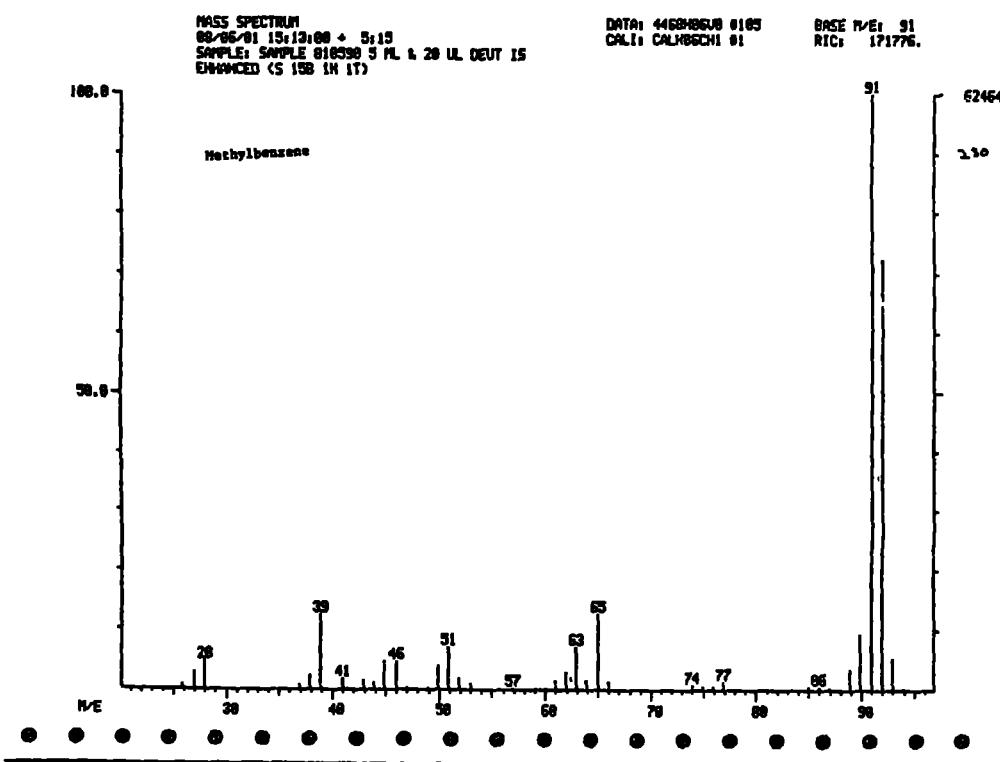


Figure 230. Mass spectrum of methylbenzene in sample 810590.

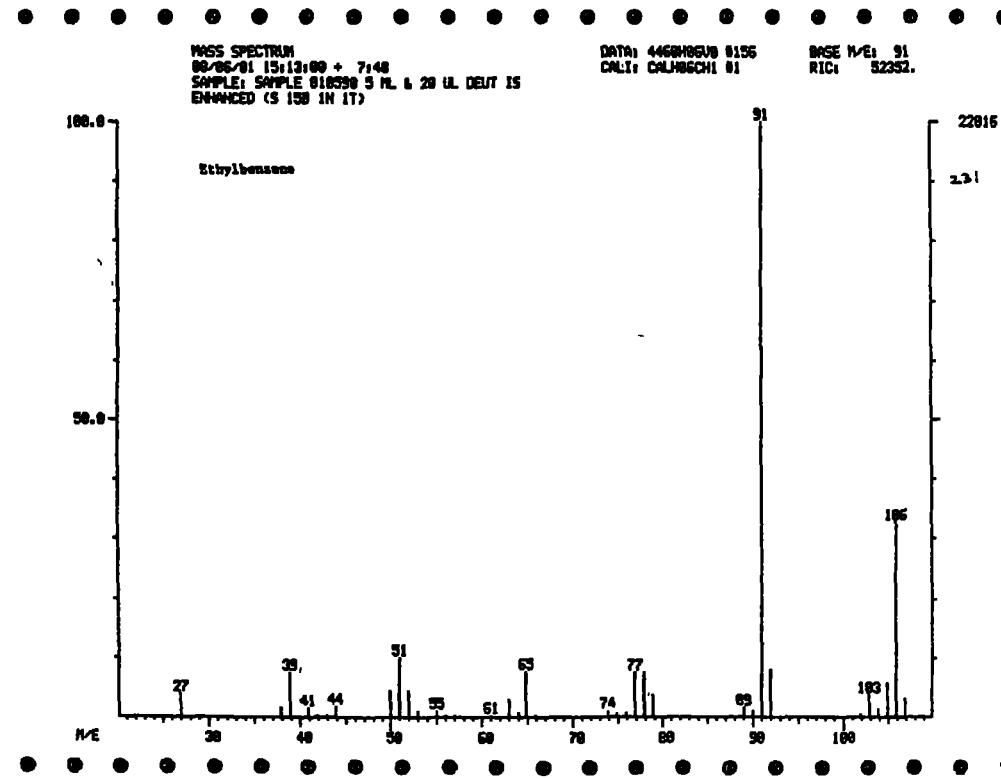


Figure 231. Mass spectrum of ethylbenzene in sample 810590.

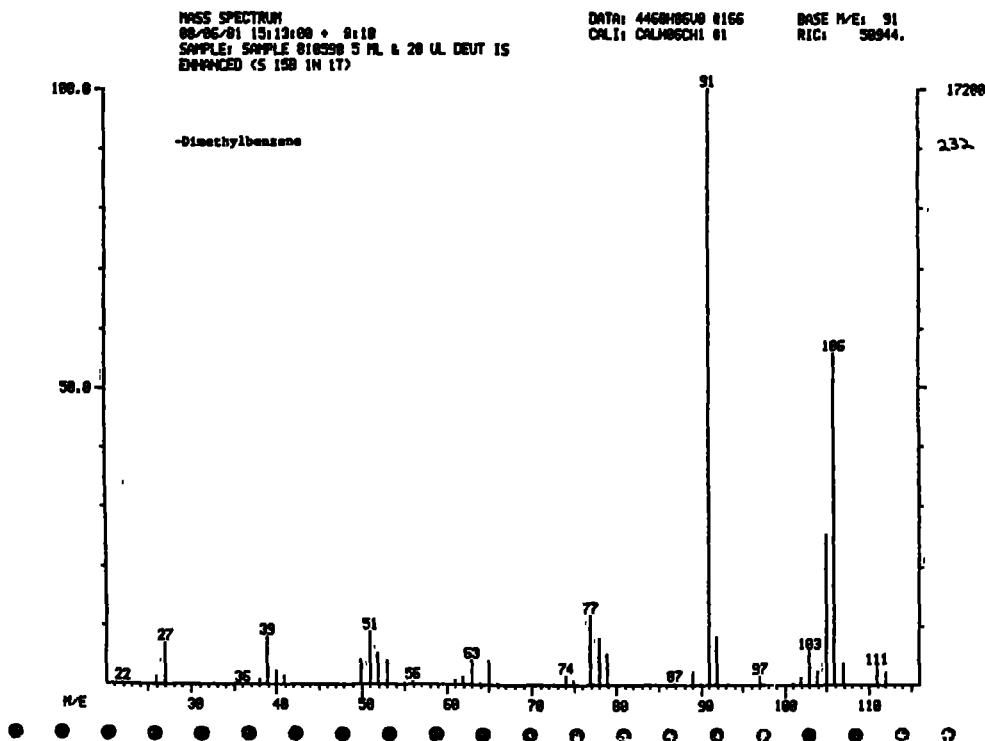


Figure 232. Mass spectrum of a dimethylbenzene in sample 810590.

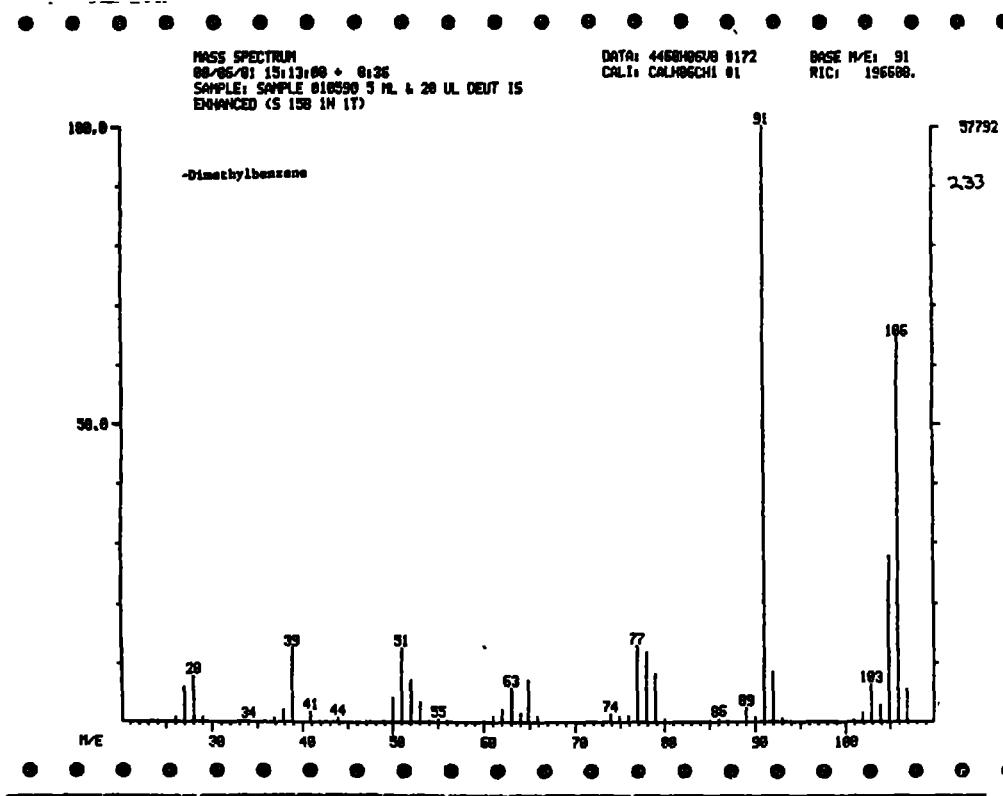


Figure 233. Mass spectrum of a dimethylbenzene in sample 810590.

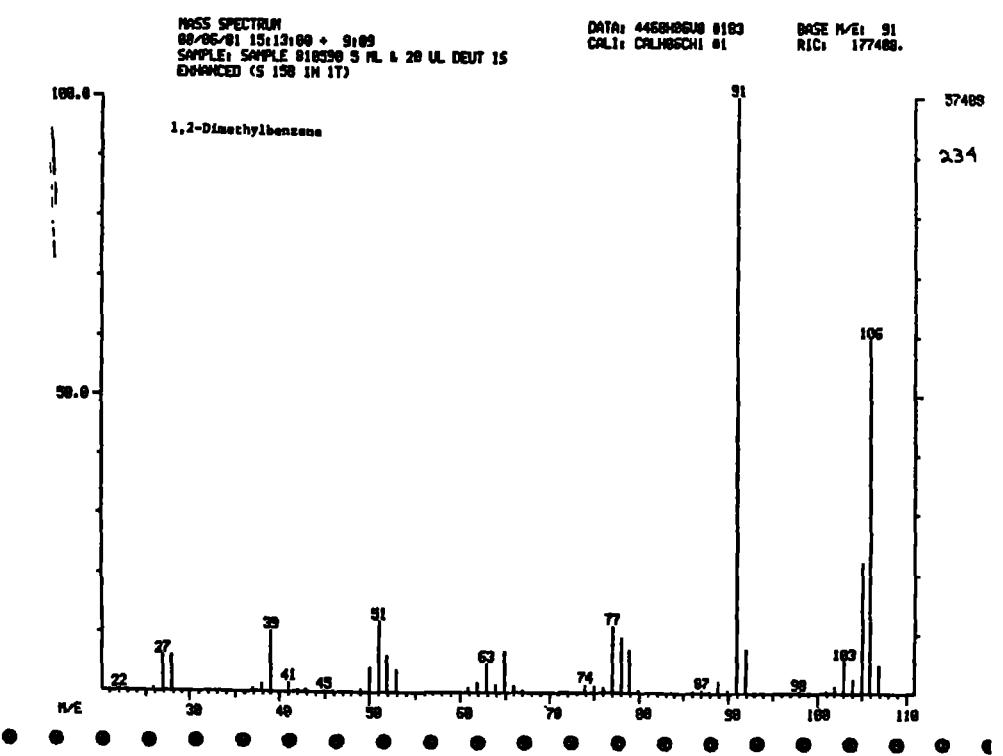


Figure 234. Mass spectrum of 1,2-dimethylbenzene in sample 810590.

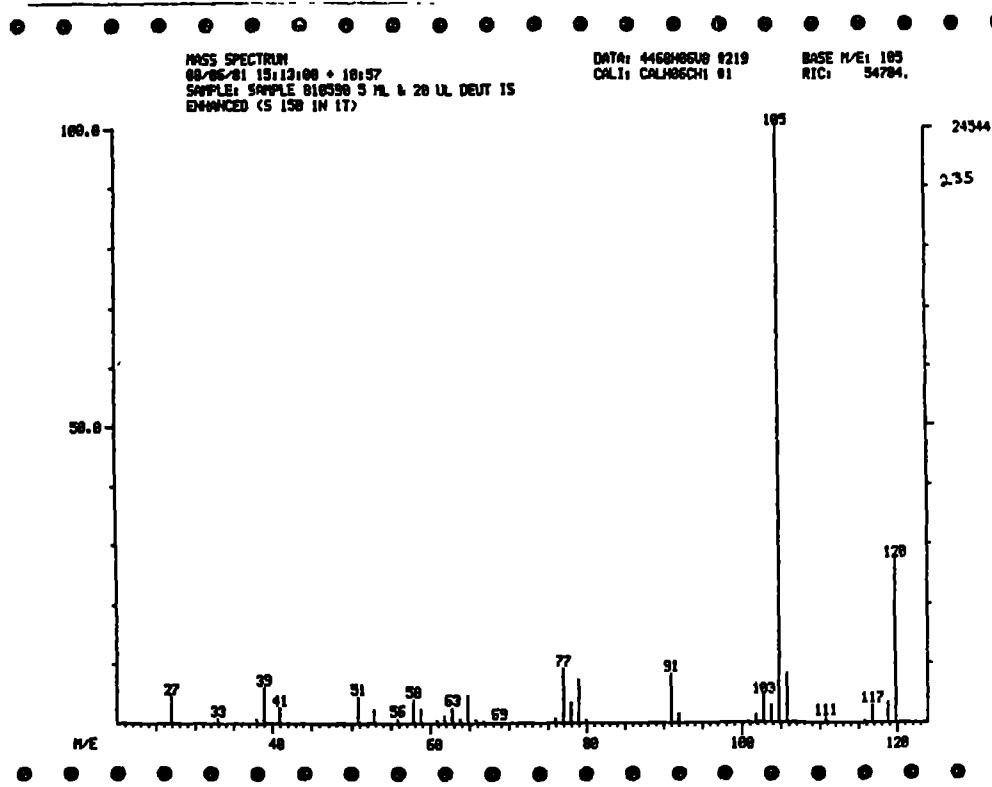


Figure 235. Mass spectrum of an ethylmethylbenzene in sample 810590.

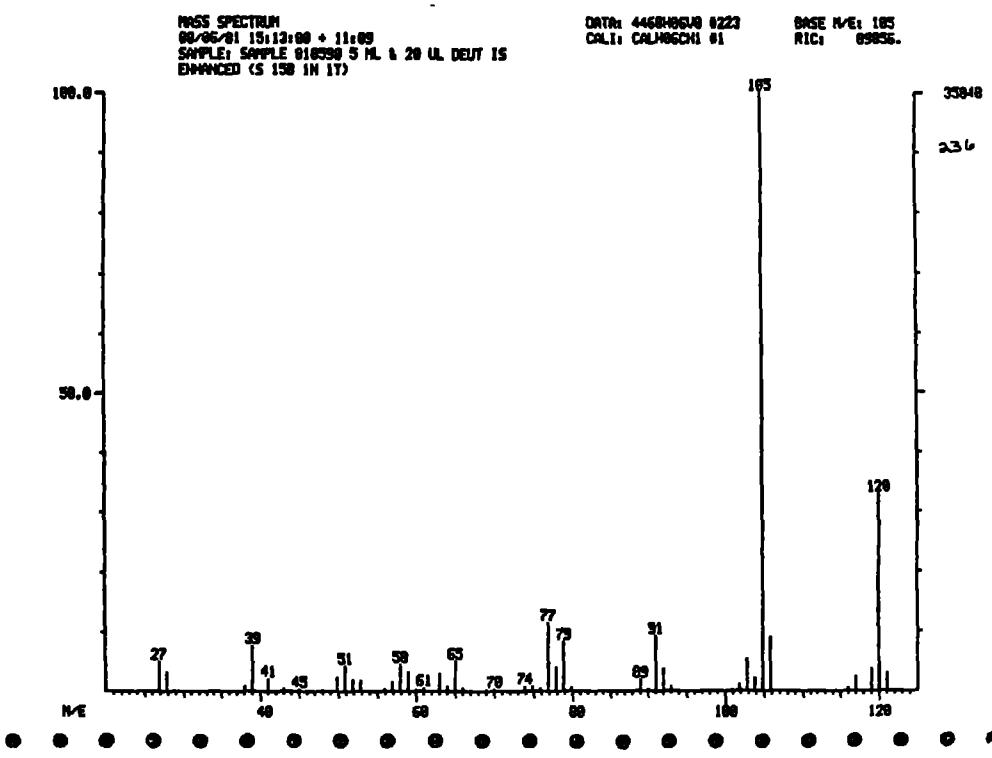


Figure 236. Mass spectrum of an ethylmethylbenzene in sample 810590.

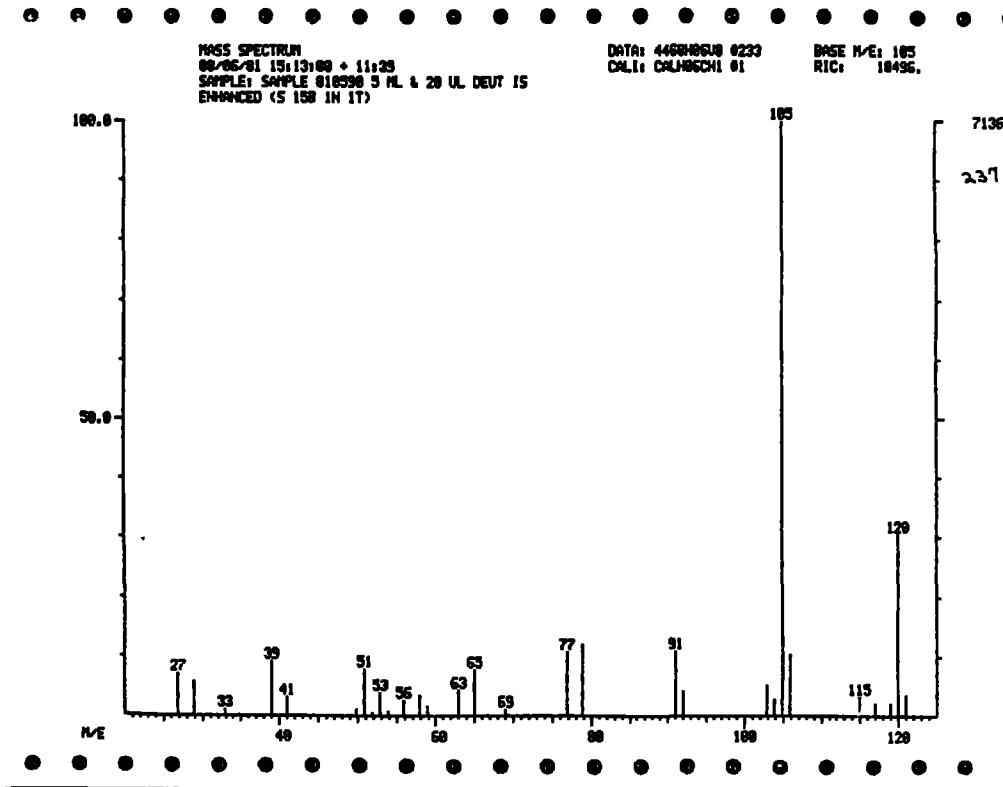


Figure 237. Mass spectrum of an ethylmethylbenzene in sample 810590.

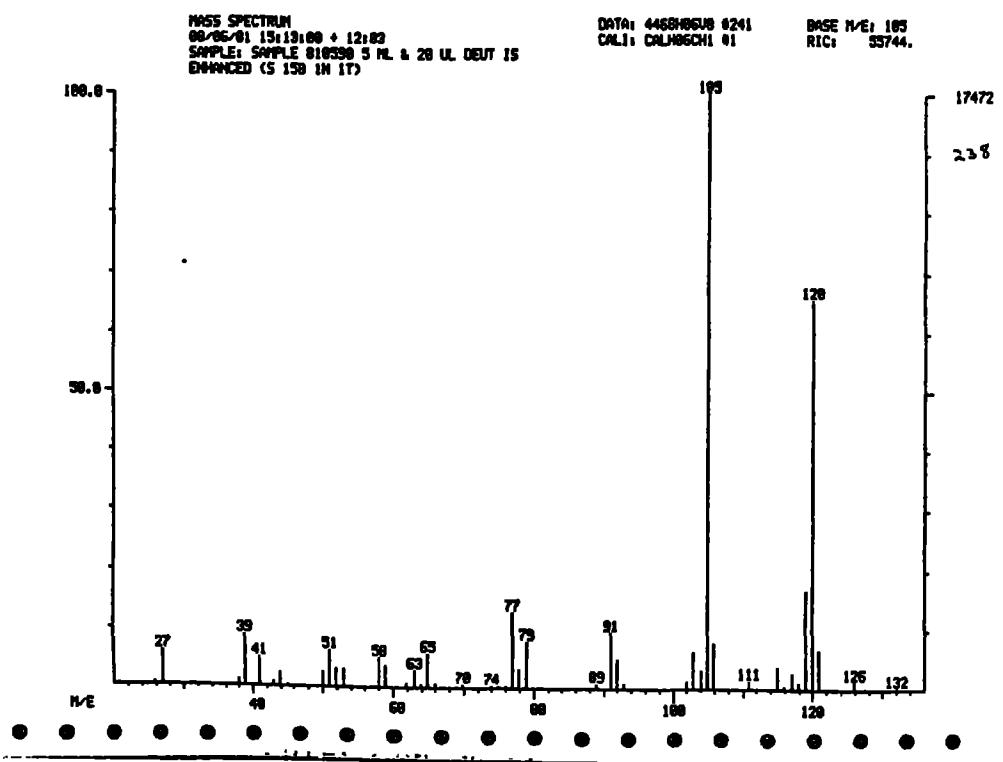


Figure 238. Mass spectrum of a trimethylbenzene in sample 810590.

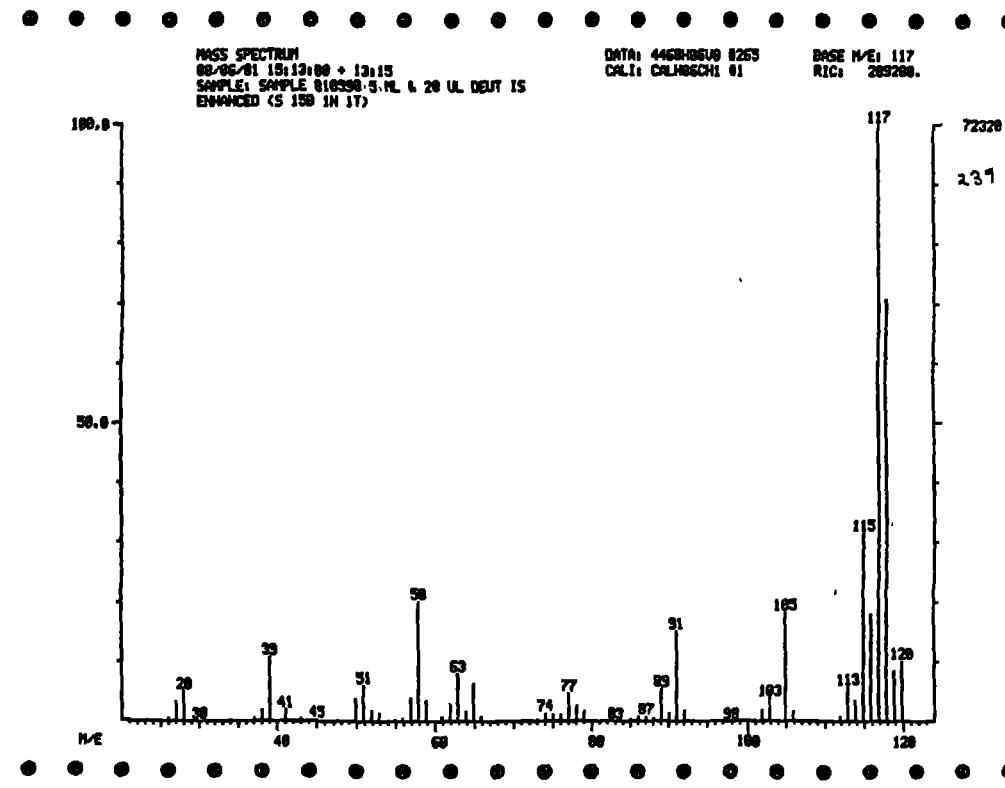


Figure 239. Mass spectrum of 2,3-dihydro-1H-indene in sample 810590.

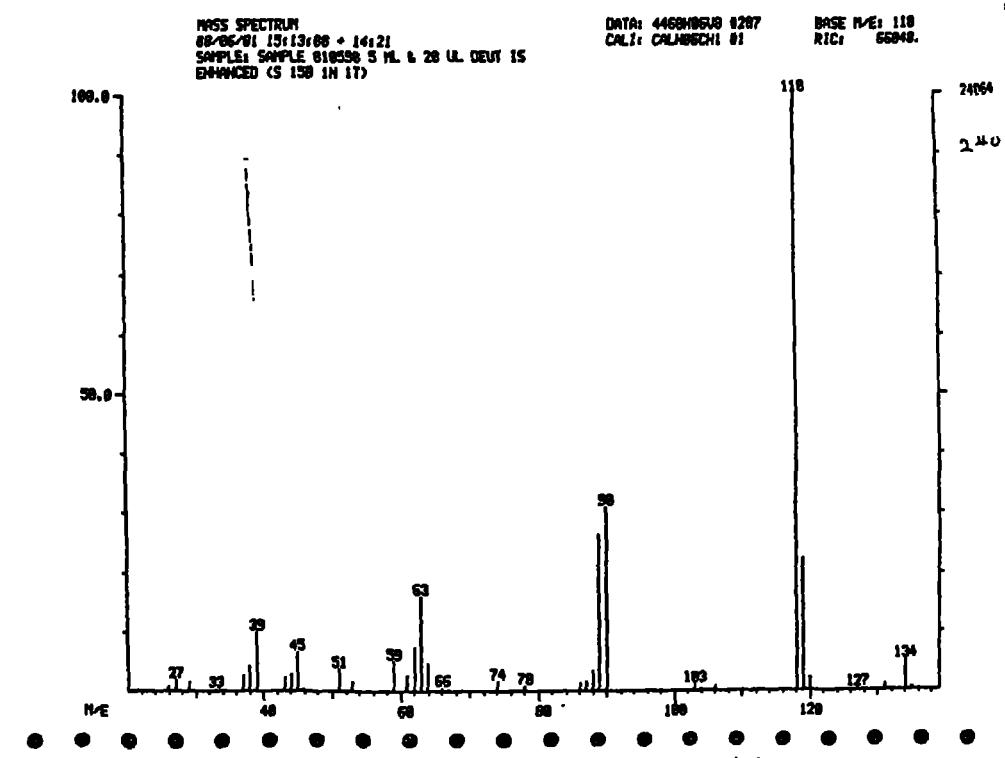


Figure 240. Mass spectrum of benzofuran in sample 810590.

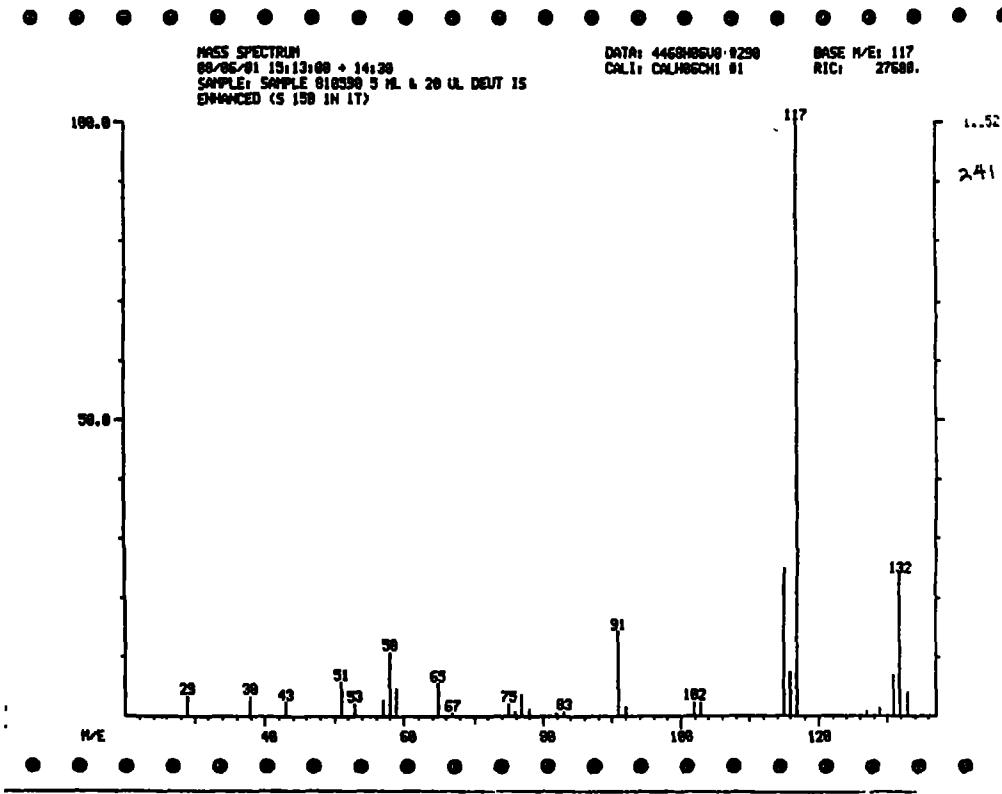


Figure 241. Mass spectrum of a methyl-2,3-dihydroindene in sample 810590.

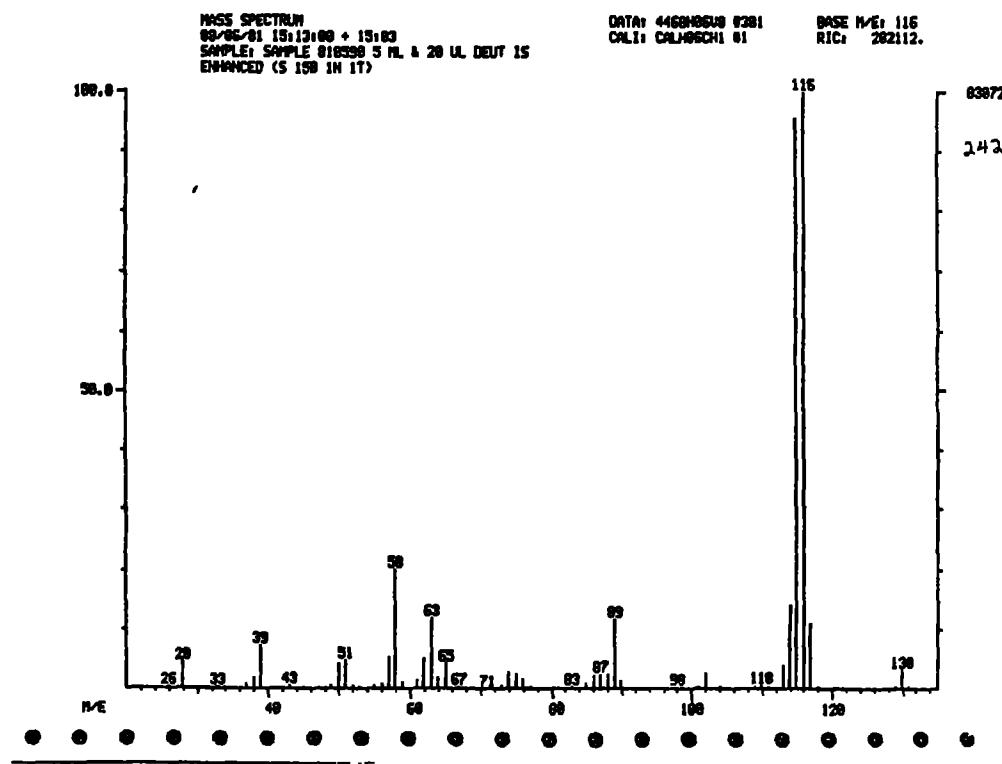


Figure 242. Mass spectrum of 1H-indene in sample 810590.

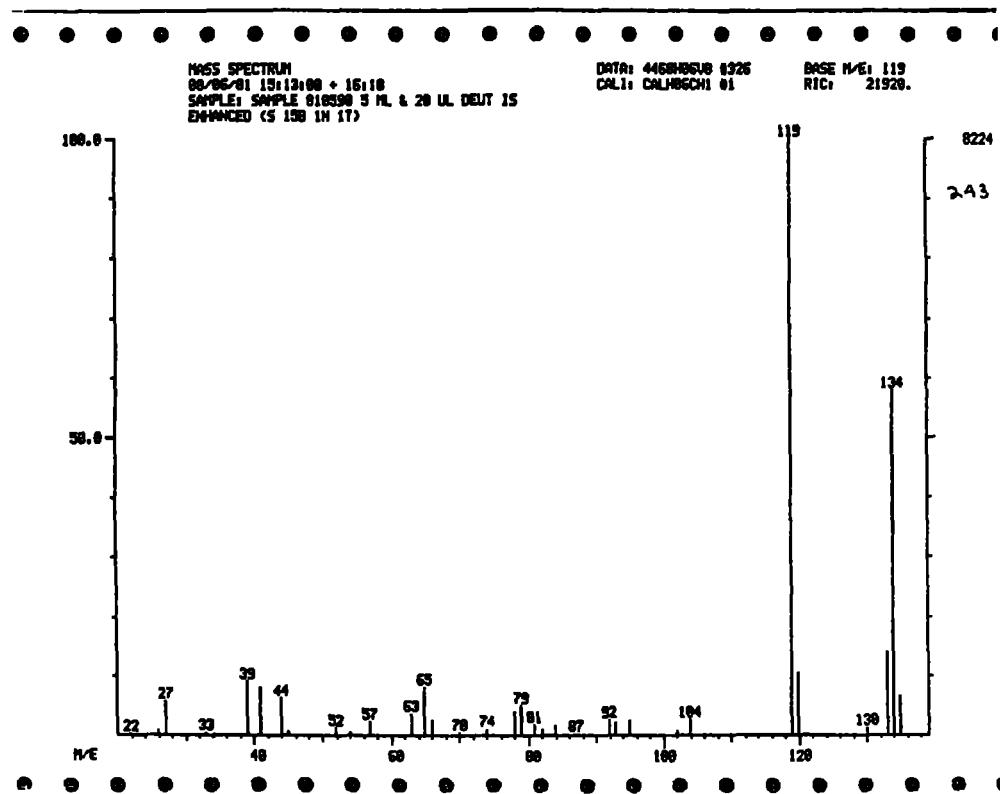


Figure 243. Mass spectrum of a tetramethylbenzene in sample 810590.

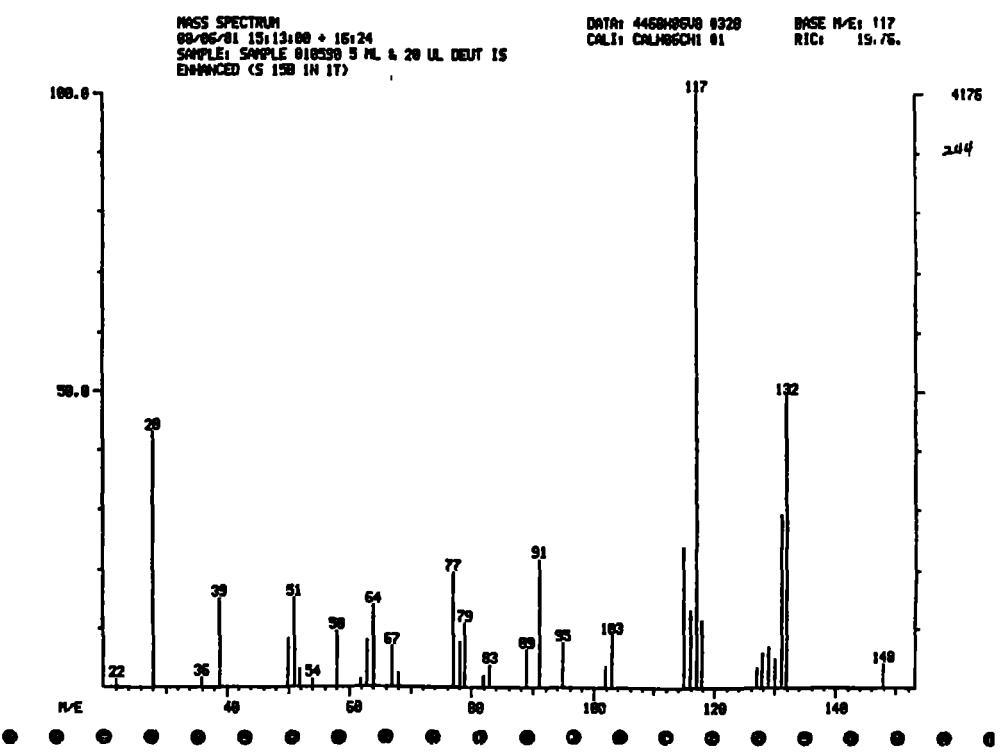


Figure 244. Mass spectrum of a methyldihydro-1H-indene in sample 810590.

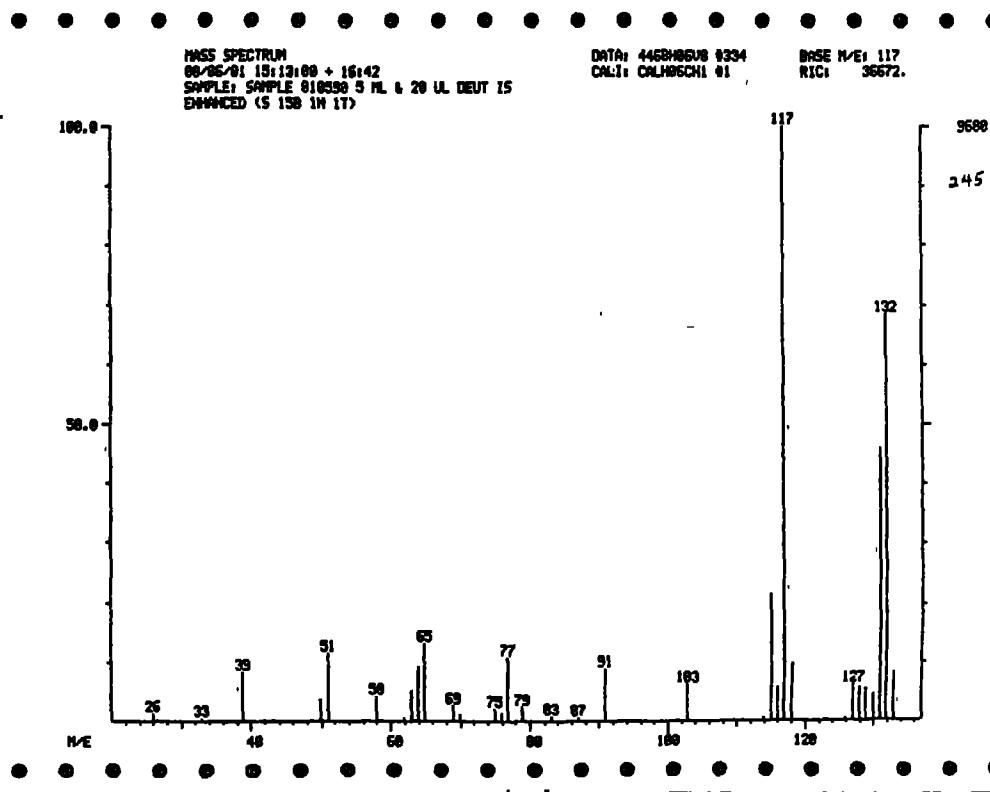


Figure 245. Mass spectrum of a methyldihydro-1H-indene in sample 810590.

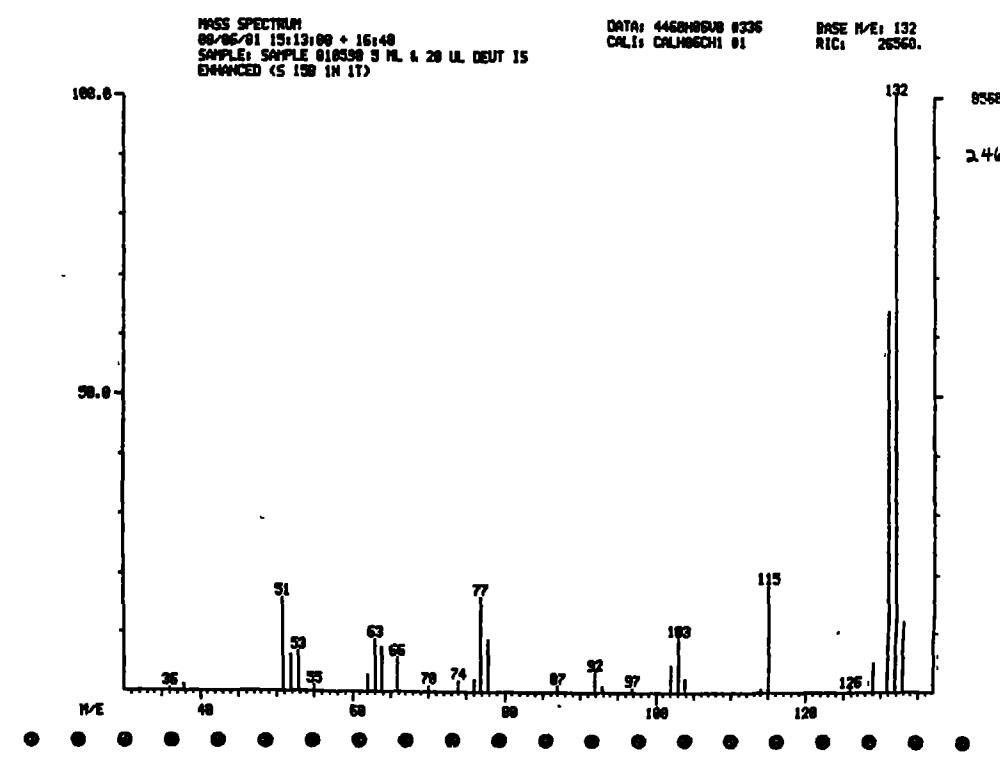


Figure 246. Mass spectrum of a methylbenzofuran in sample 810590.

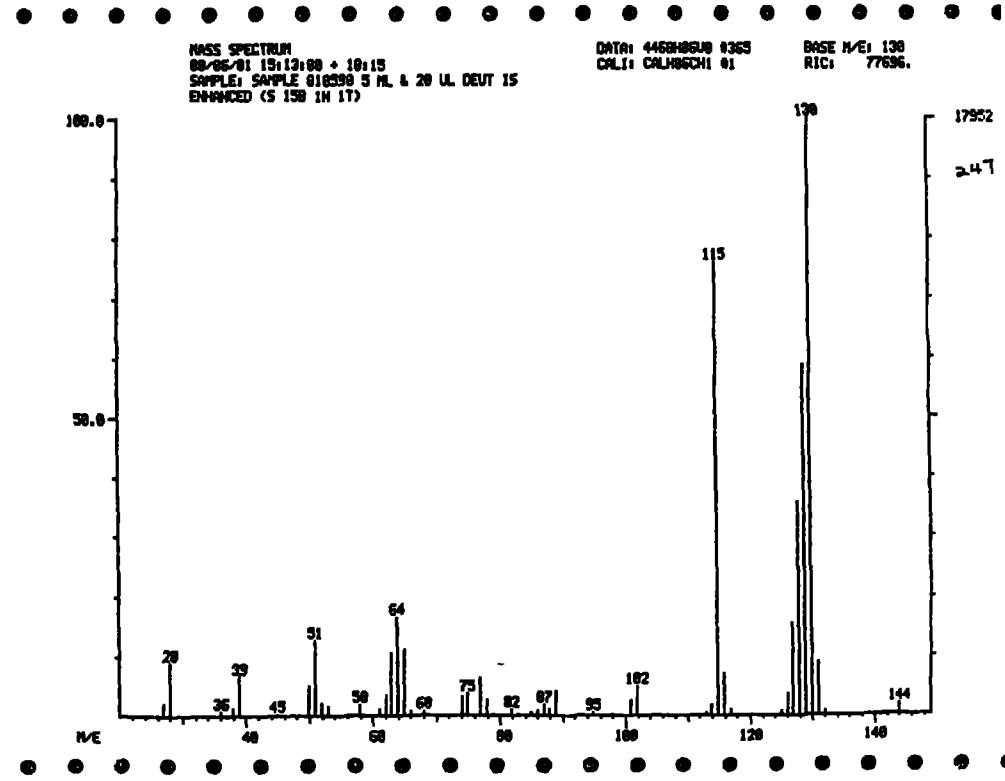


Figure 247. Mass spectrum of 1-methylindene in sample 810590.

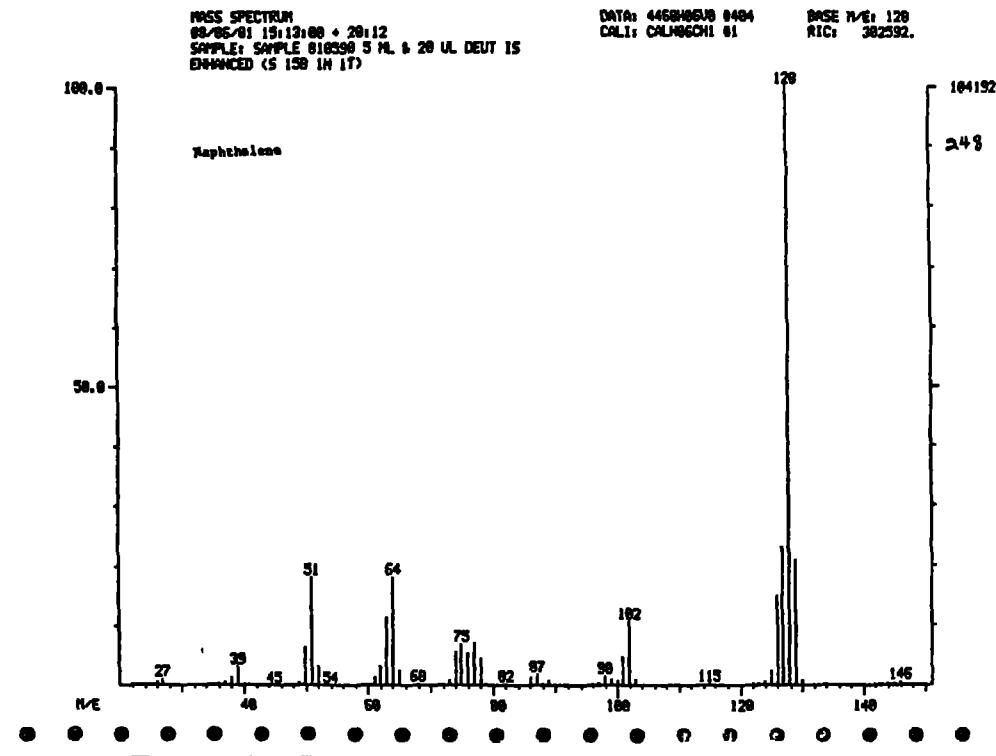


Figure 248. Mass spectrum of naphthalene in sample 810590.

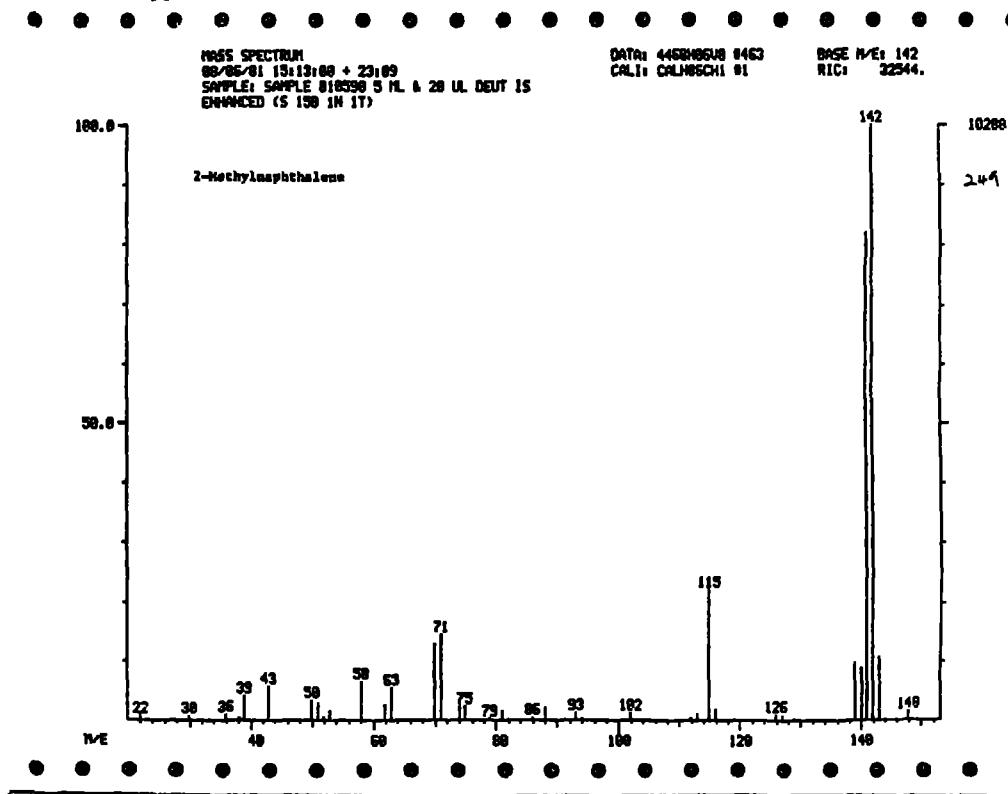


Figure 249. Mass spectrum of 2-methylnaphthalene in sample 810590.

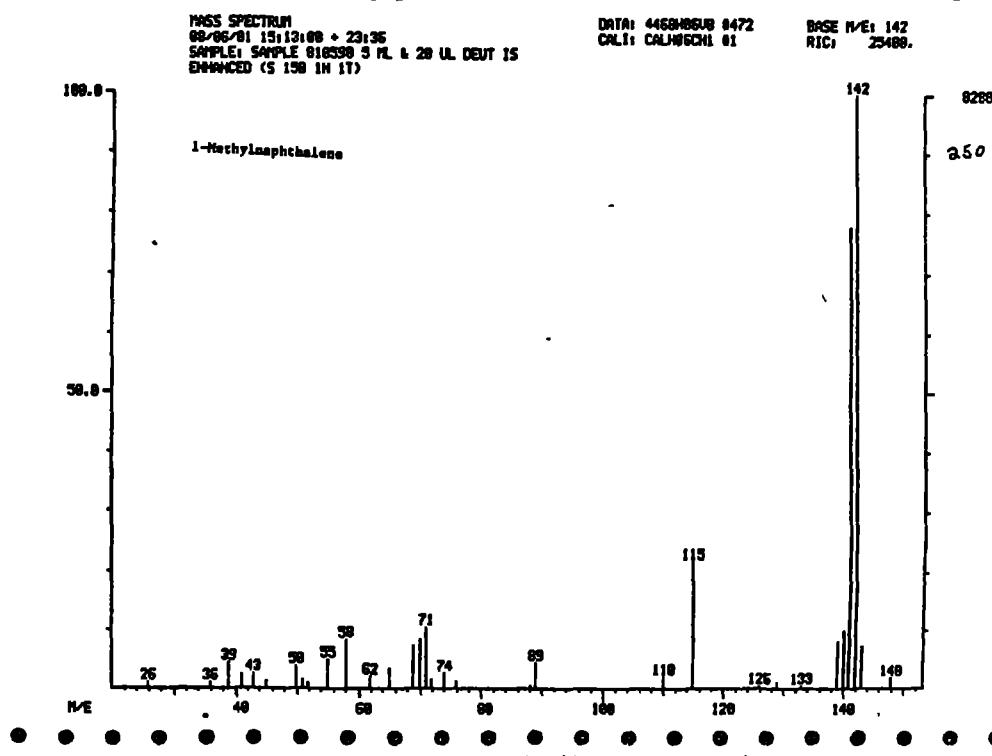


Figure 250. Mass spectrum of 1-methylnaphthalene in sample 810590.

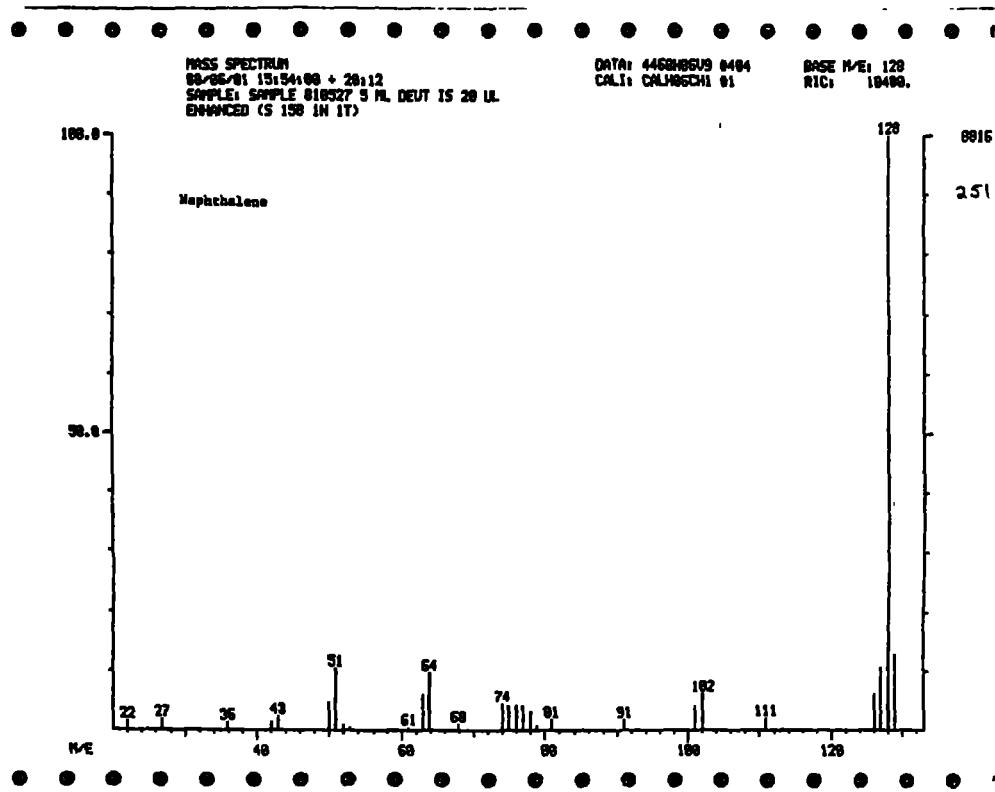


Figure 251. Mass spectrum of naphthalene in sample 810527.

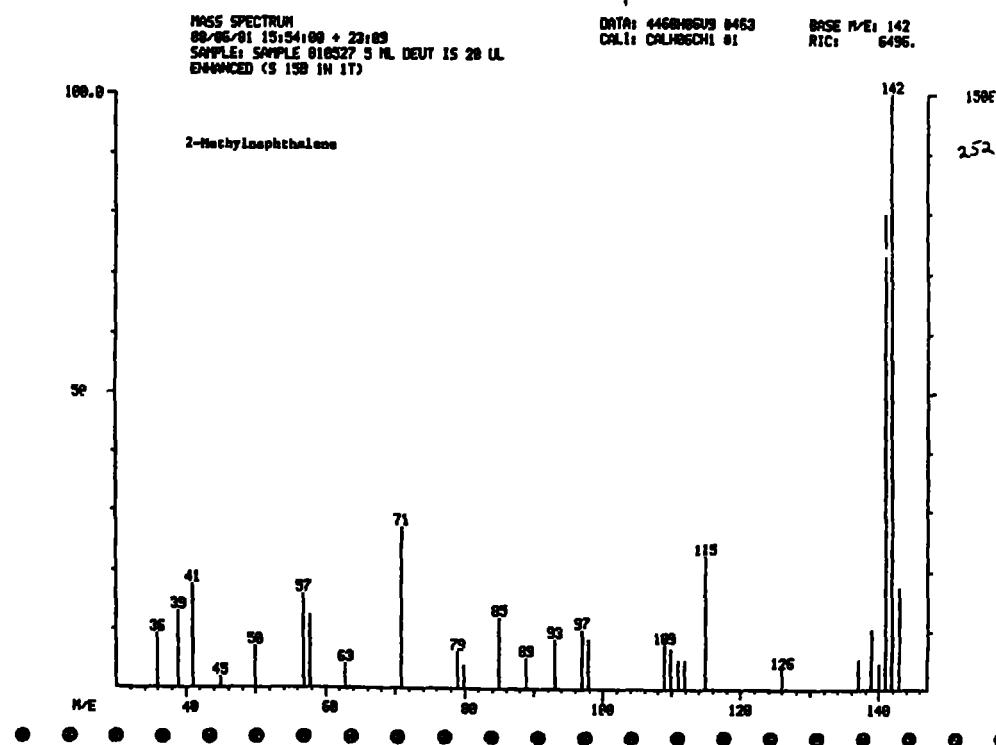


Figure 252. Mass spectrum of 2-methylnaphthalene in sample 810527.

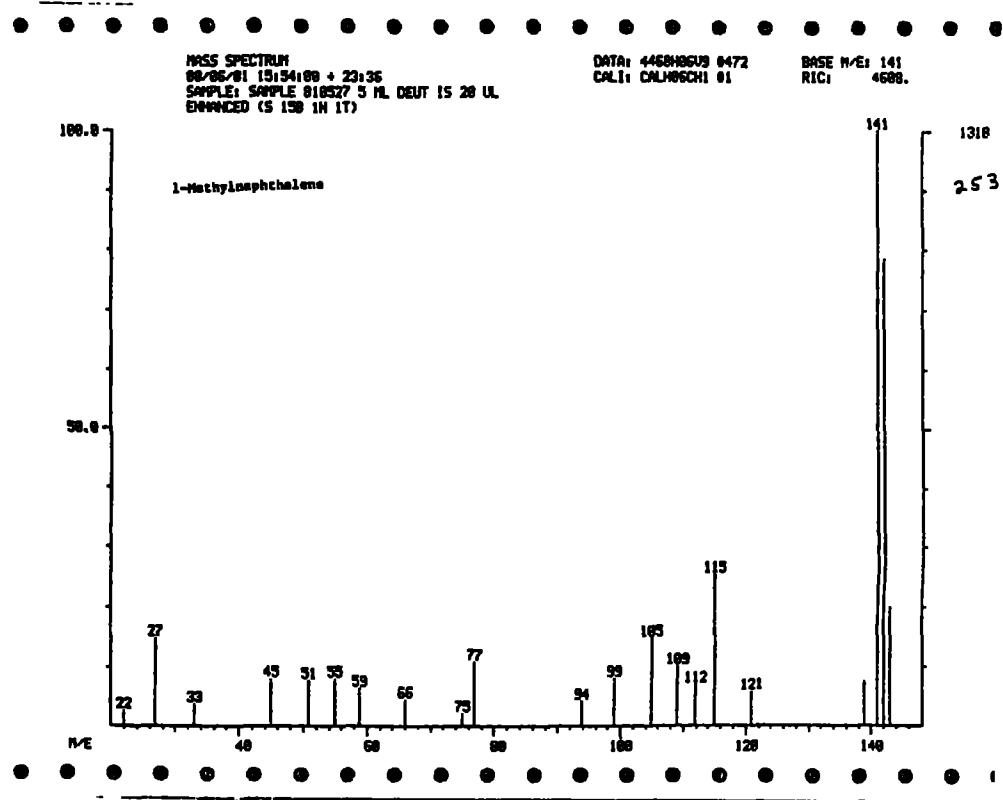


Figure 253. Mass spectrum of 1-methylenaphthalene in sample 810527.

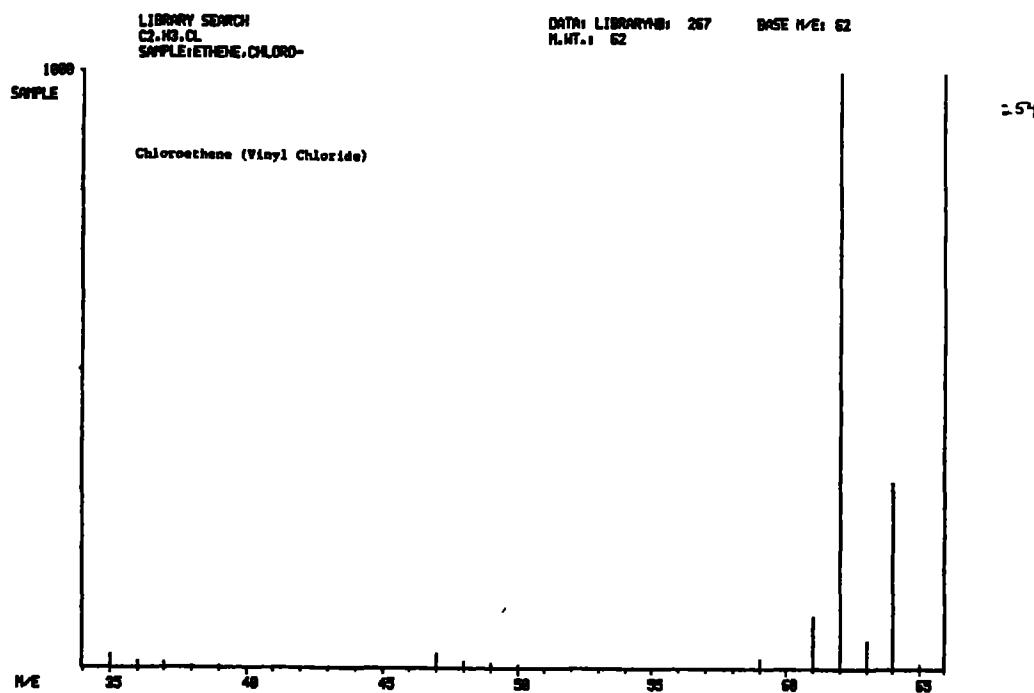


Figure 254. Mass spectrum of chloroethene (vinyl chloride) from computer library.

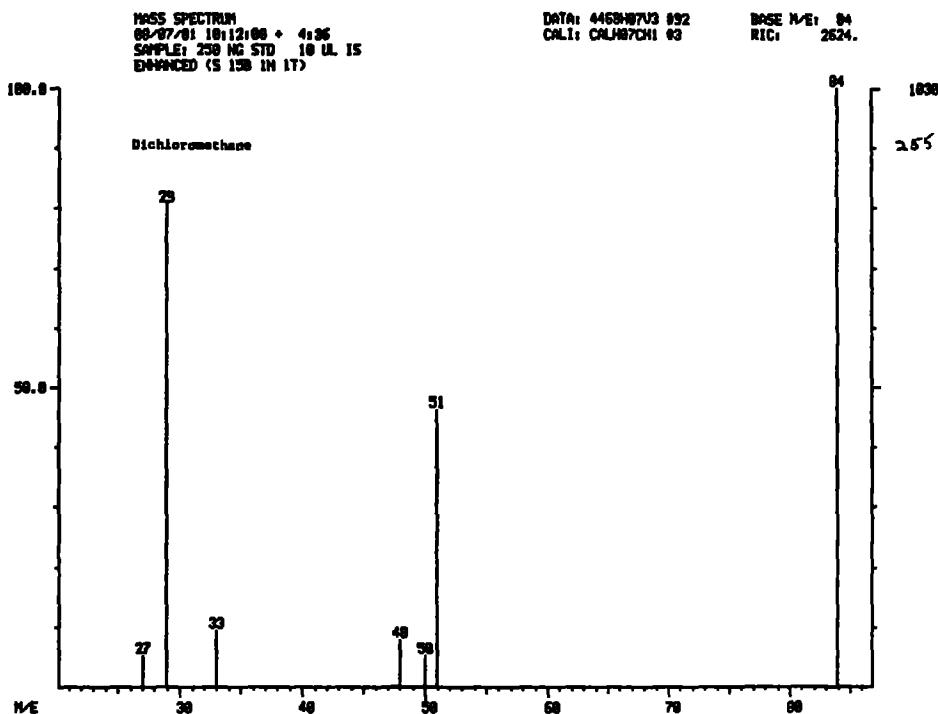


Figure 255. Mass spectrum of dichloromethane in standard.

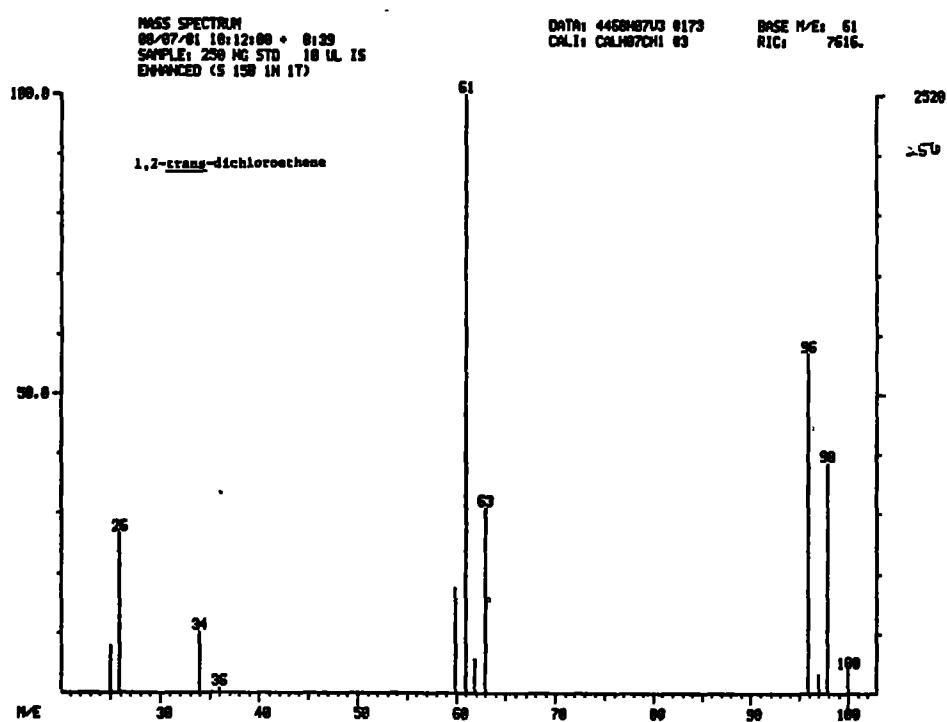


Figure 256. Mass spectrum of 1,2-trans-dichloroethene in standard.

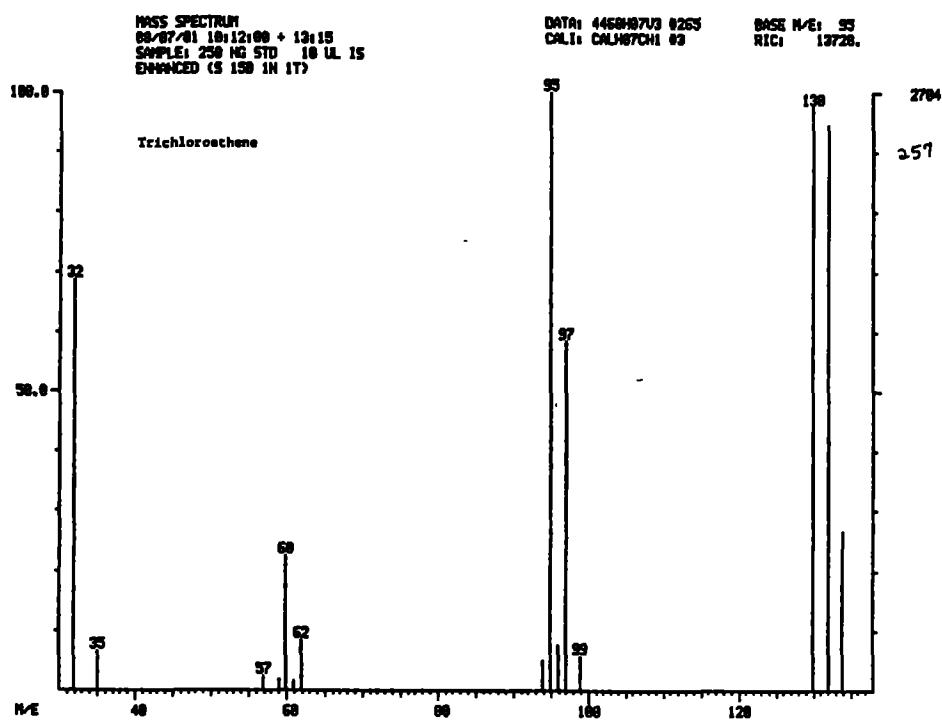


Figure 257. Mass spectrum of trichloroethene in standard.

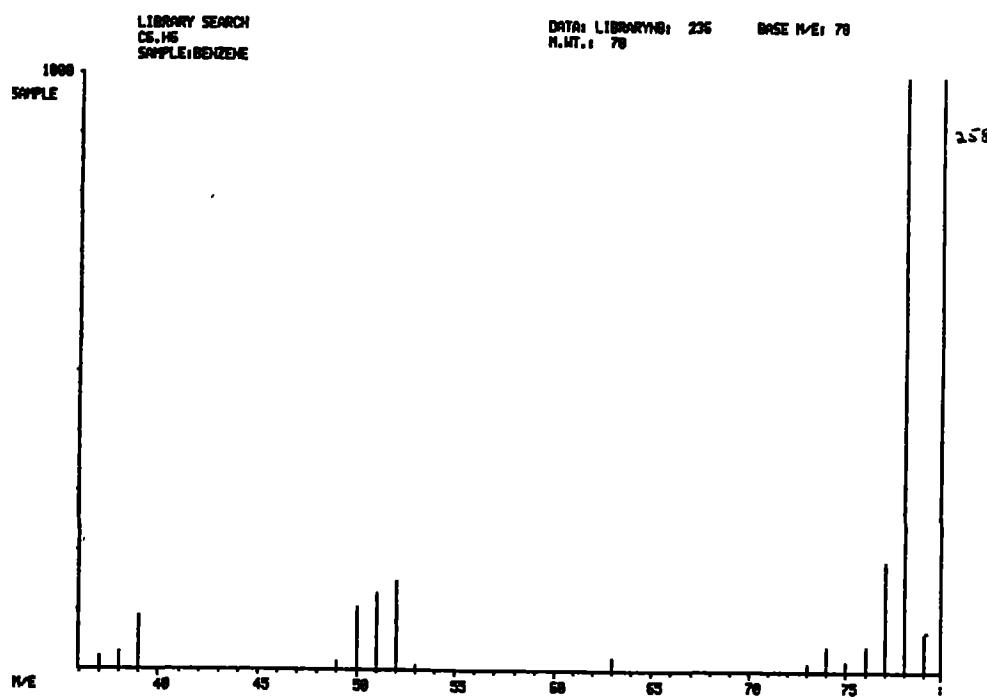


Figure 258. Mass spectrum of benzene from computer library.

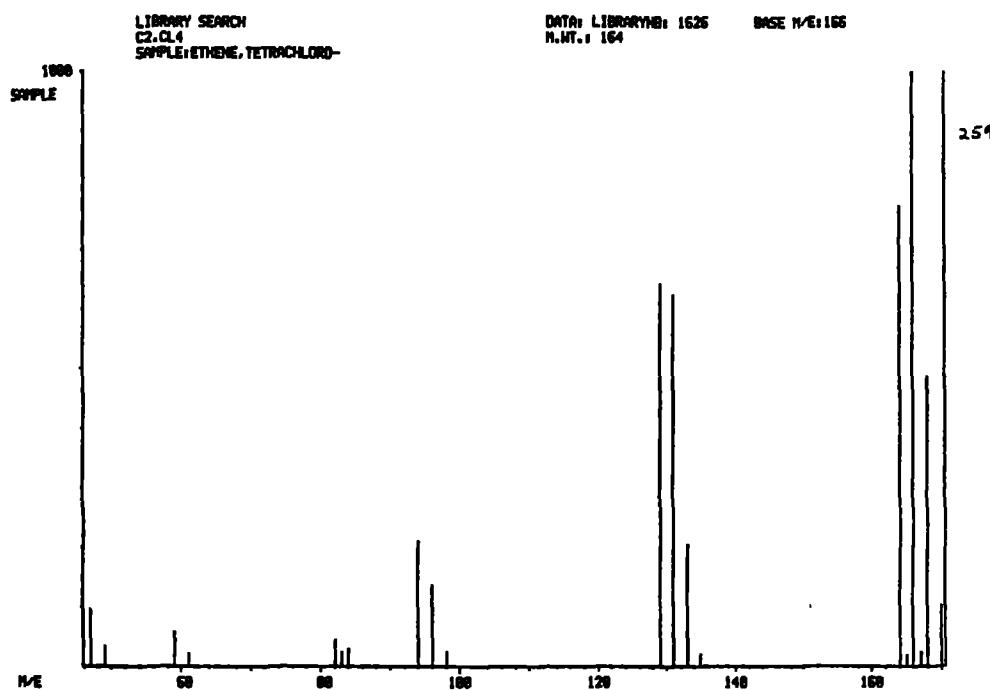


Figure 259. Mass spectrum of tetrachloroethene from computer library.

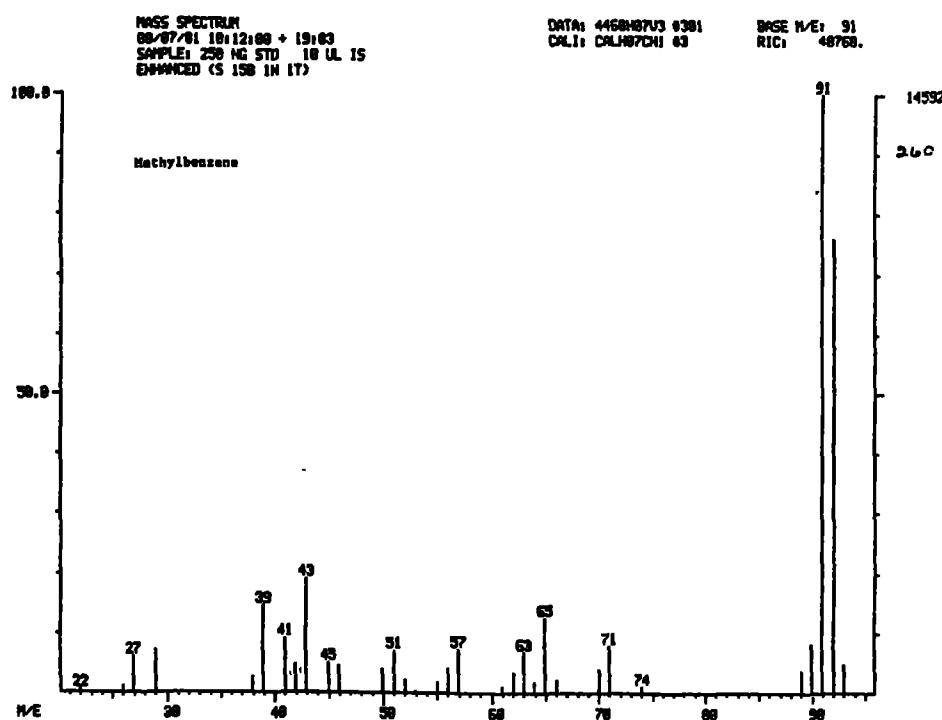


Figure 260. Mass spectrum of methylbenzene from standard.

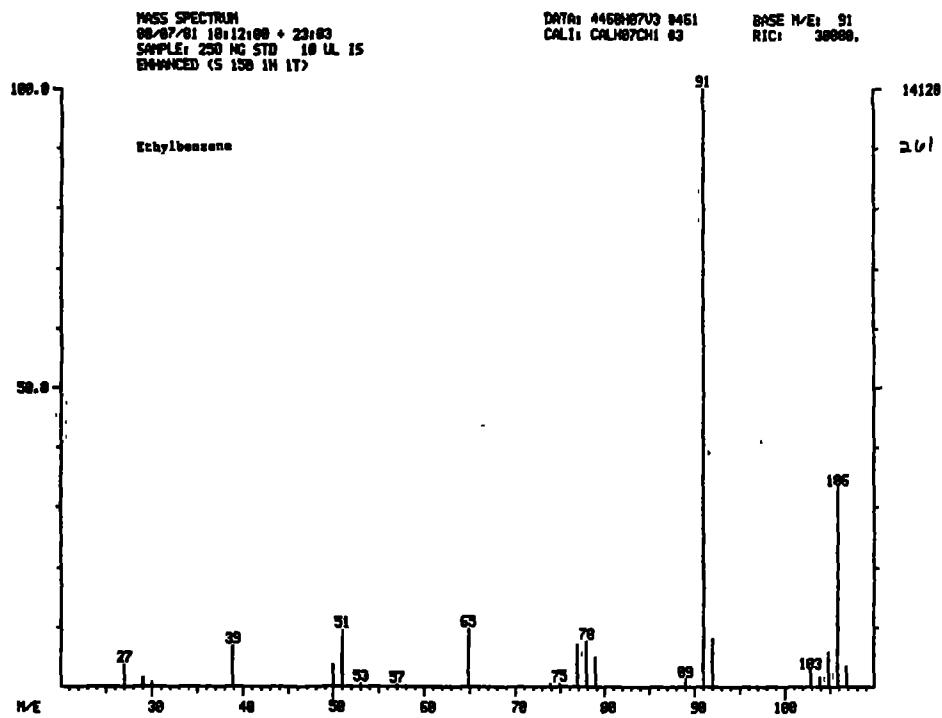


Figure 261. Mass spectrum of ethylbenzene in standard.

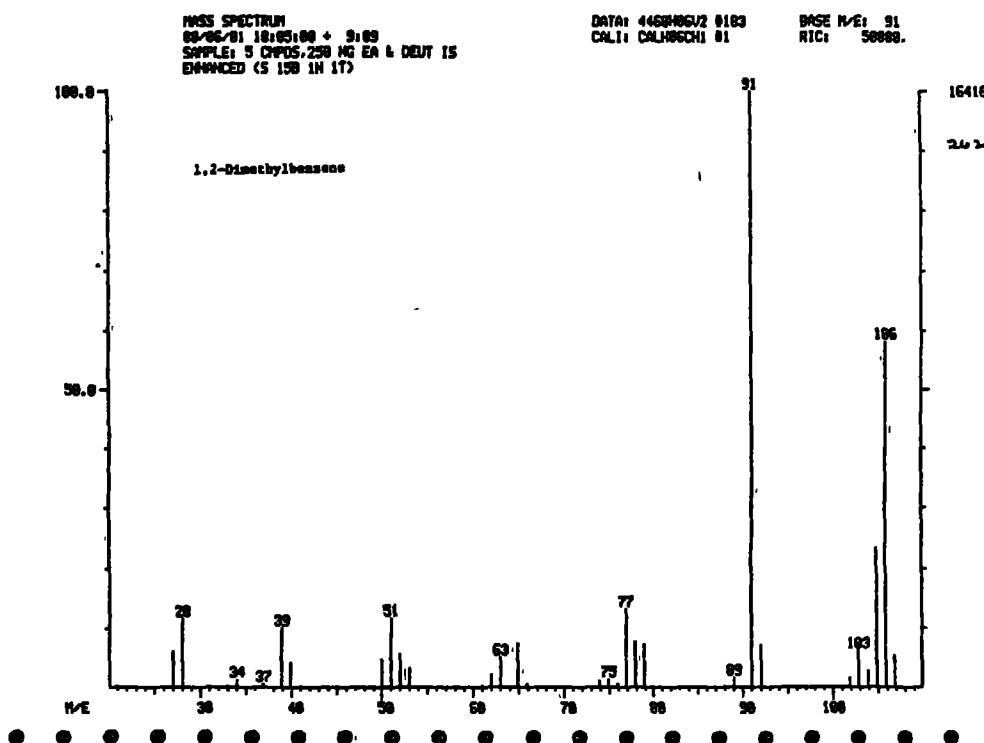


Figure 262. Mass spectrum of 1,2-dimethylbenzene from standard.

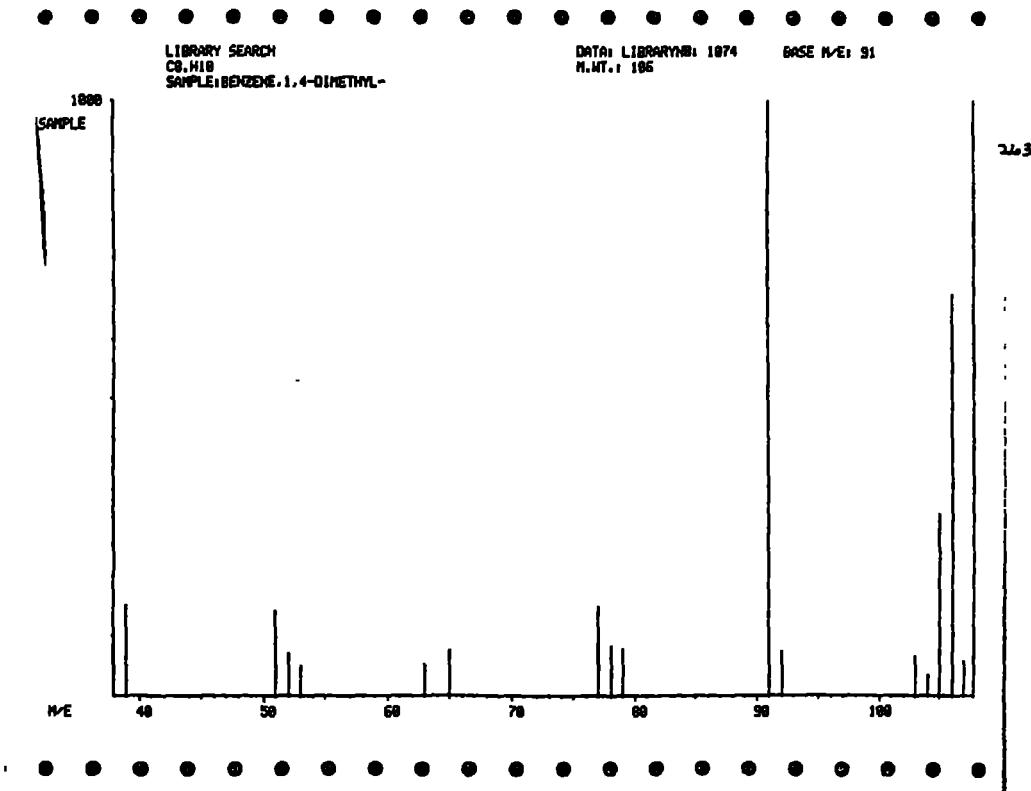


Figure 263. Mass spectrum of a dimethylbenzene from computer library.

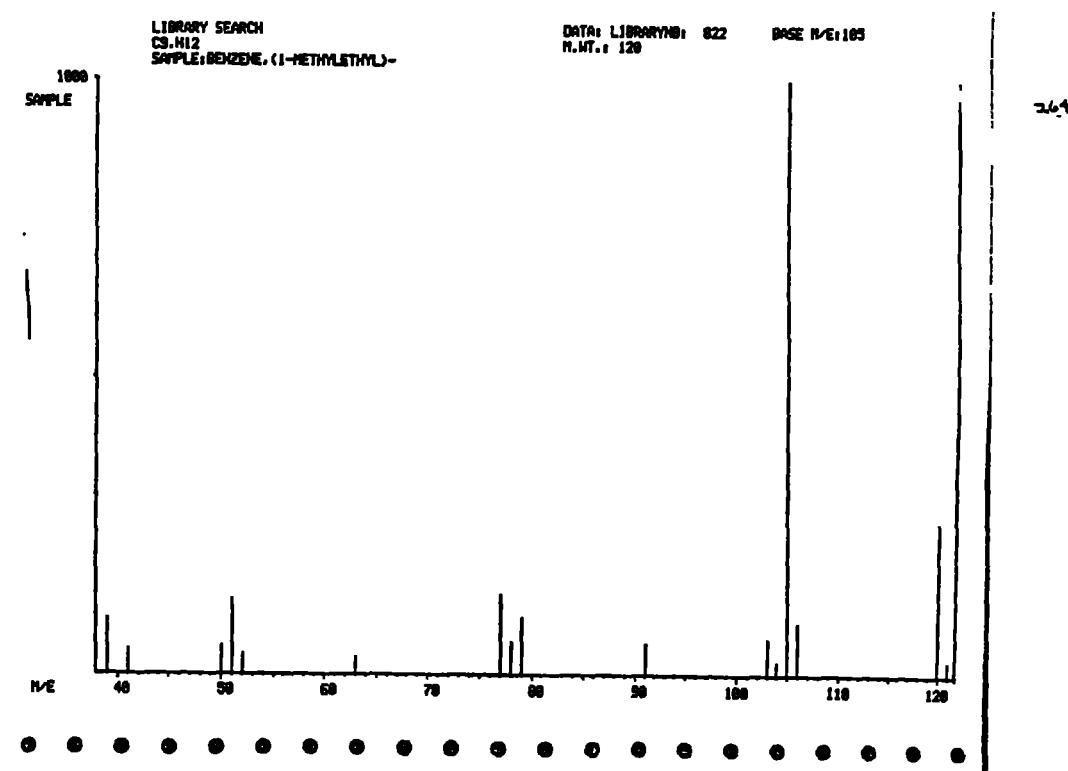


Figure 264. Mass spectrum of isopropyl benzene from computer library.

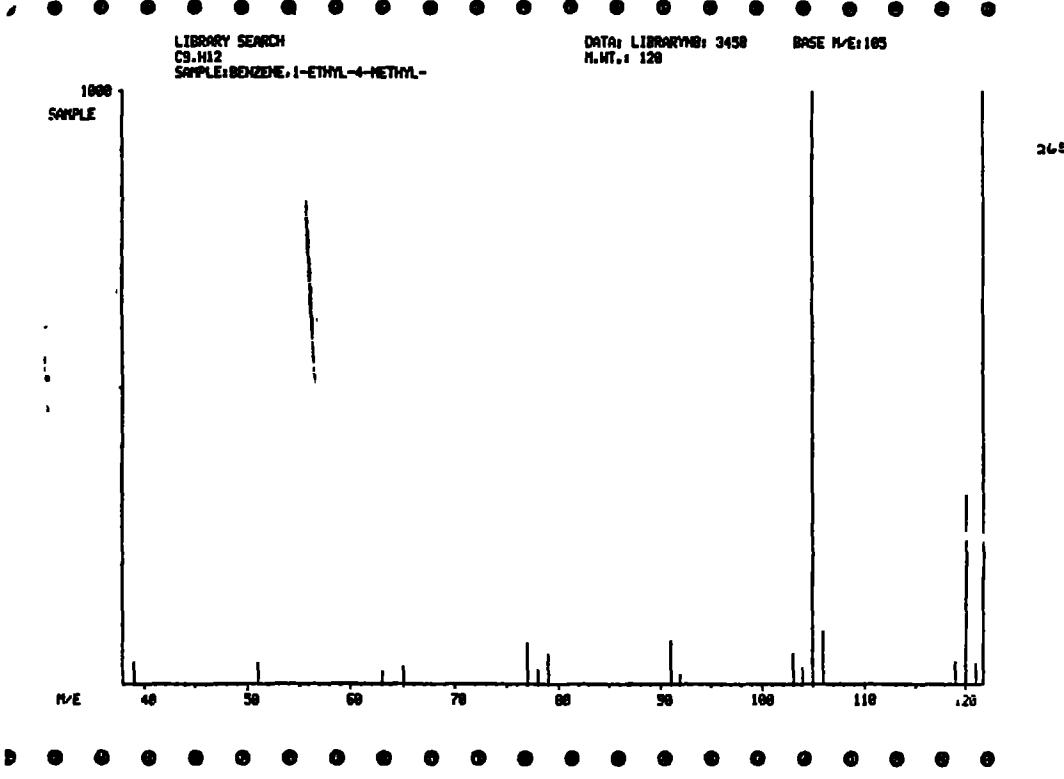


Figure 265. Mass spectrum of an ethylmethylbenzene from computer library.

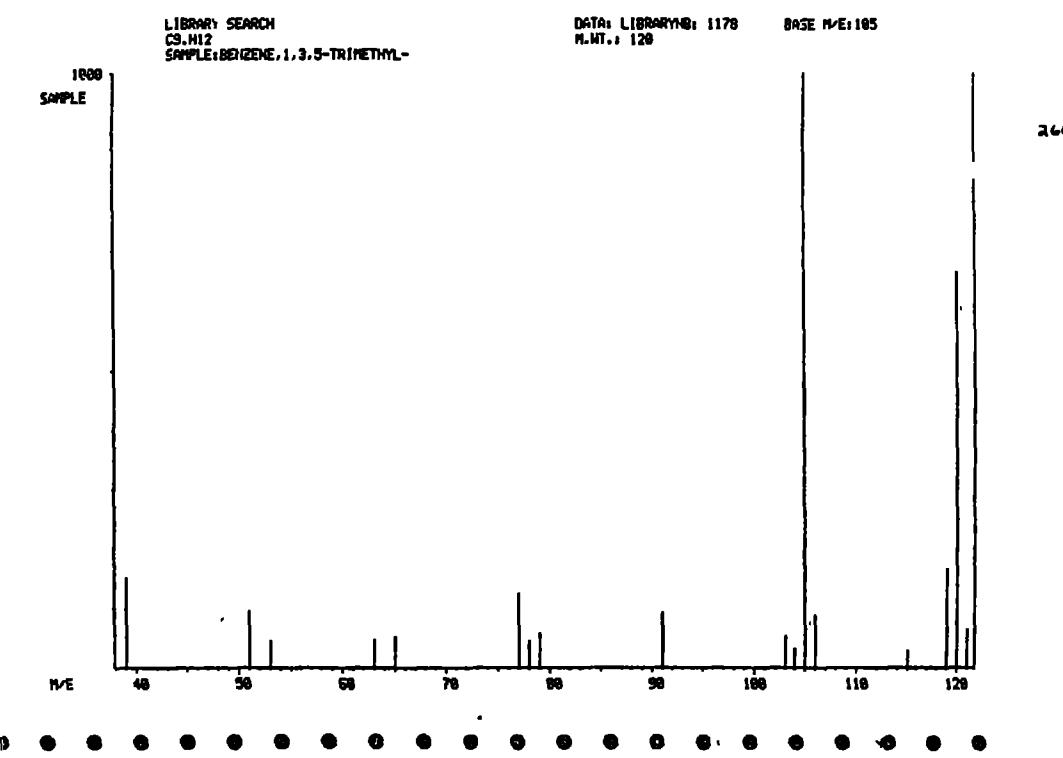


Figure 266. Mass spectrum of a trimethylbenzene from computer library.

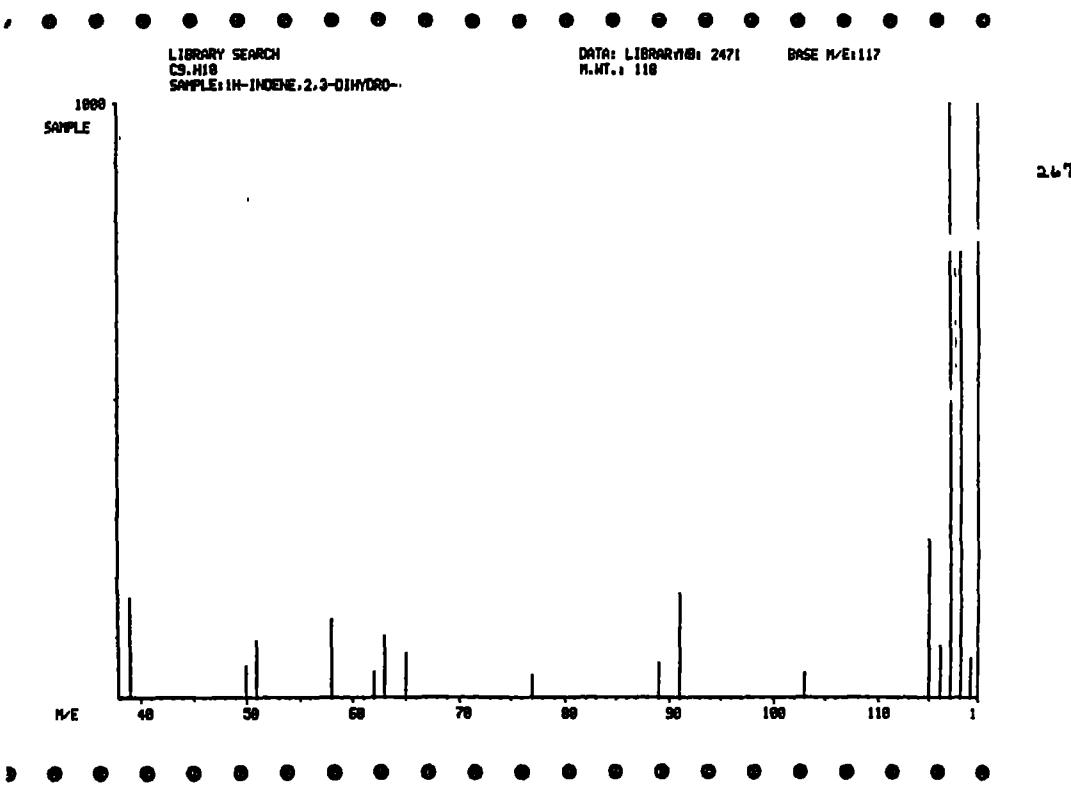


Figure 267. Mass spectrum of 2,3-dihydro-1H-indene from computer library.

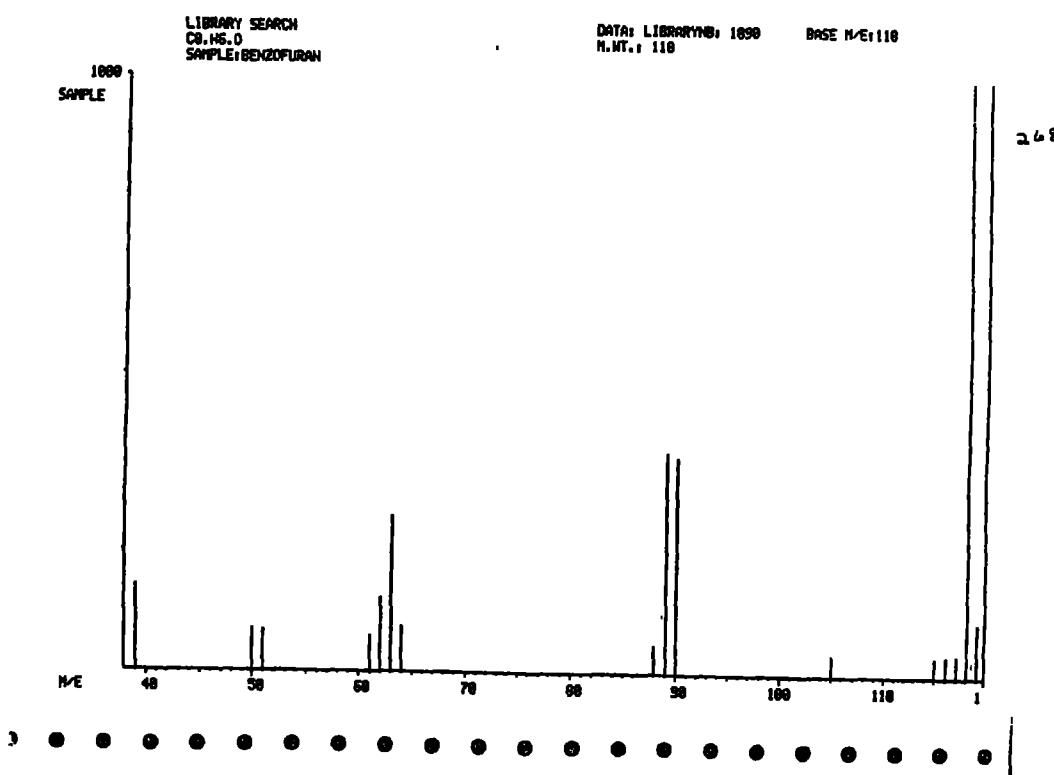


Figure 268. Mass spectrum of benzofuran from computer library.

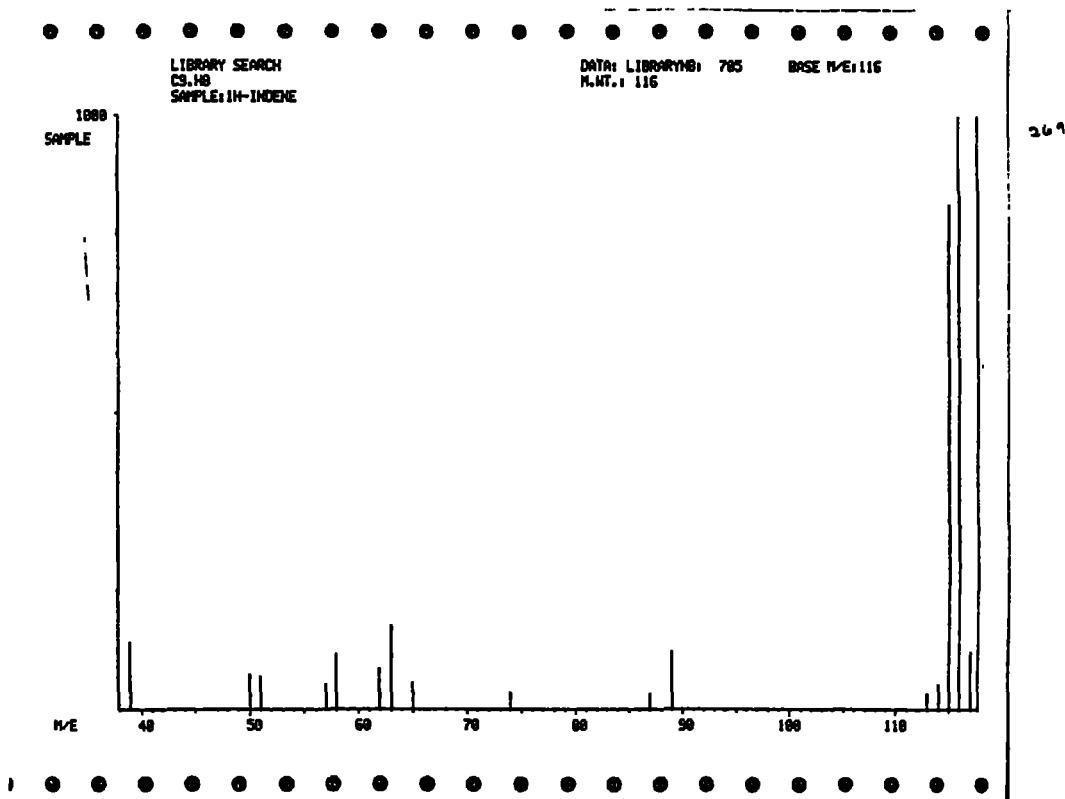


Figure 269. Mass spectrum of 1H-indene from computer library.

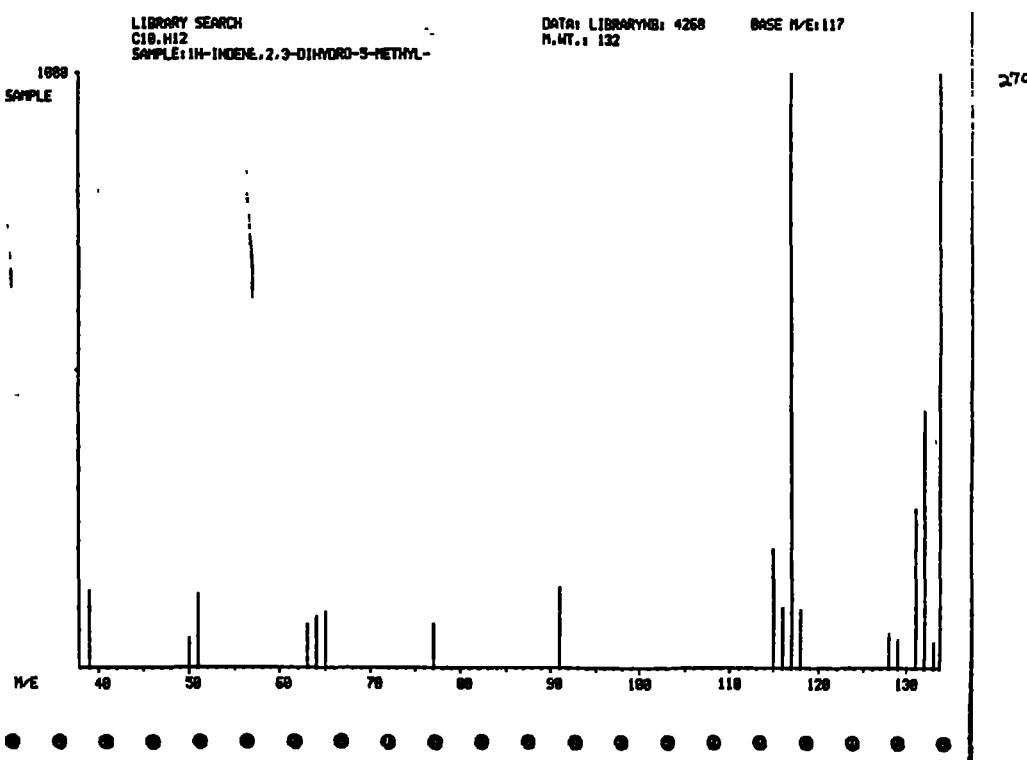


Figure 270. Mass spectrum of 5-methyl-2,3-dihydro-1H-indene from computer library.

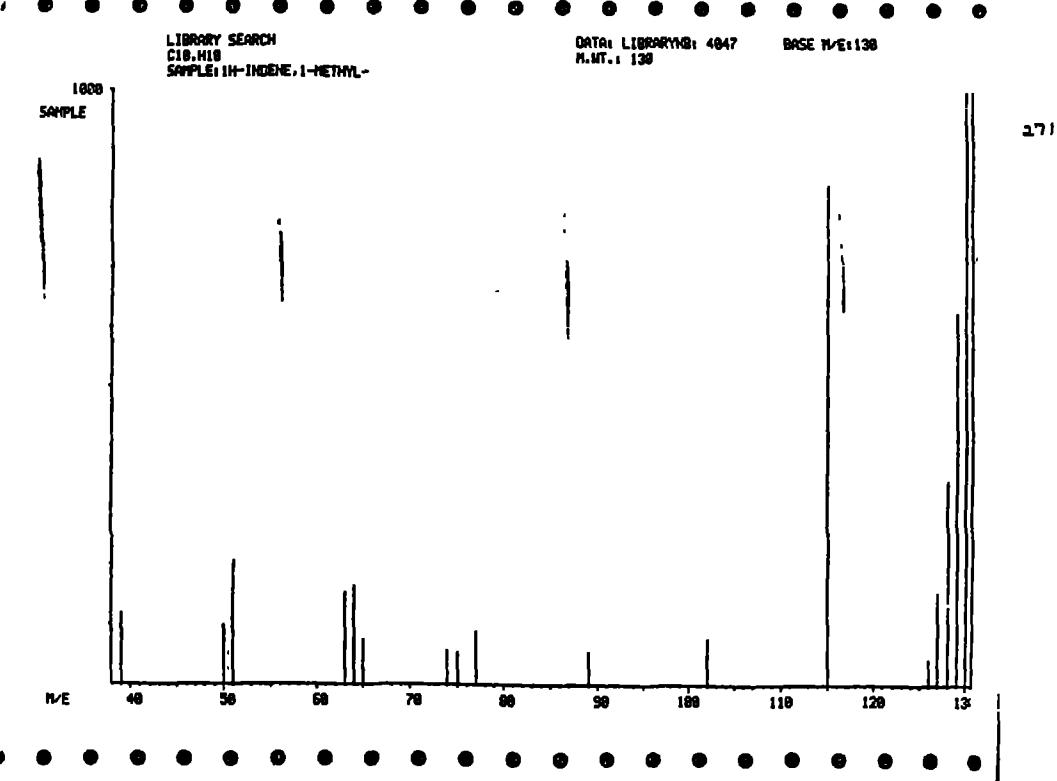


Figure 271. Mass spectrum of 1-methyl-1H-indene from computer library.

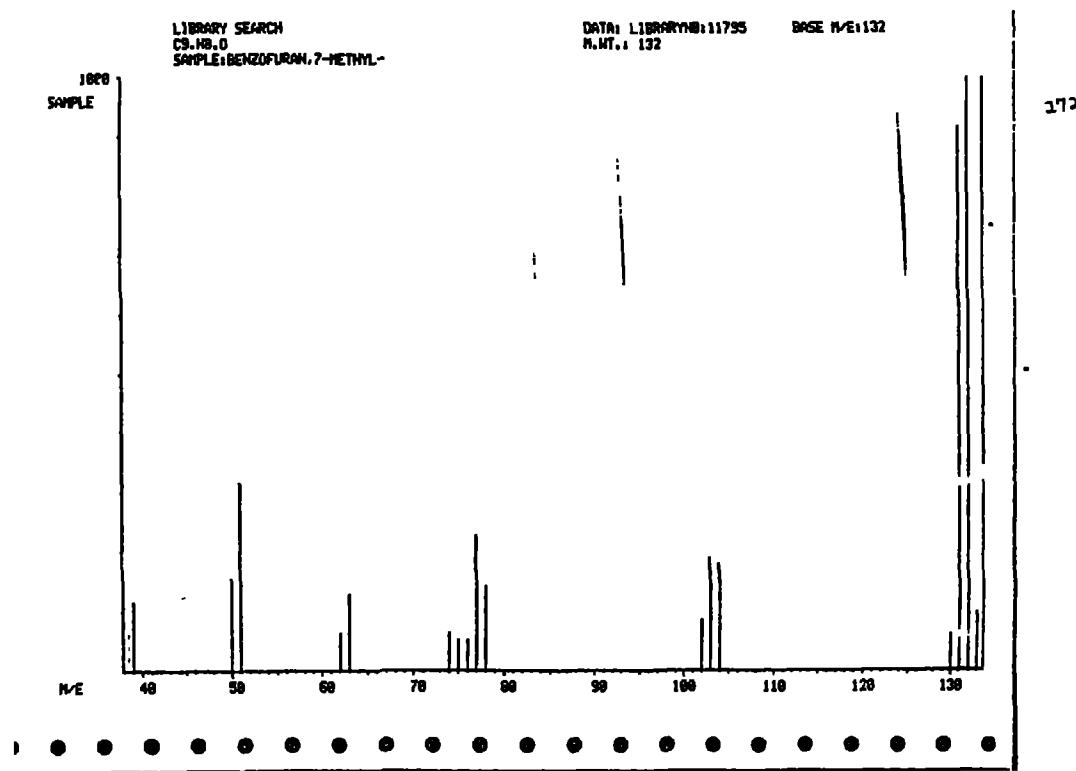


Figure 272. Mass spectrum of 7-methylbenzofuran from computer library.

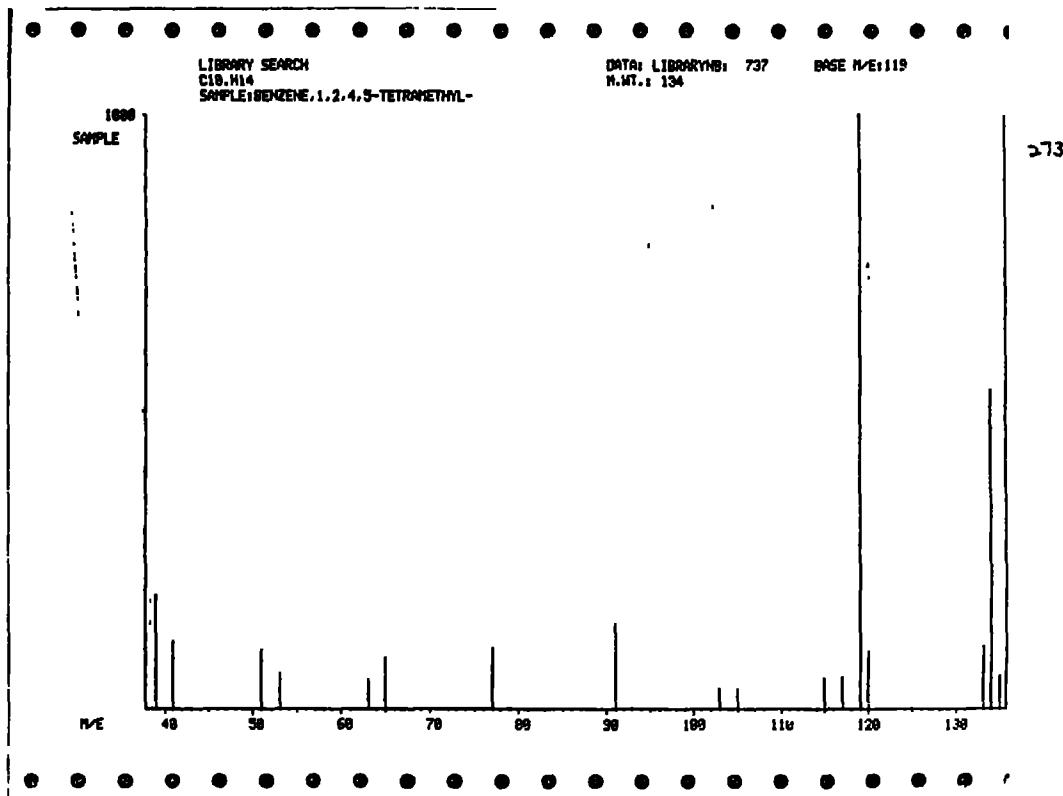


Figure 273. Mass spectrum of a tetramethylbenzene from computer library.

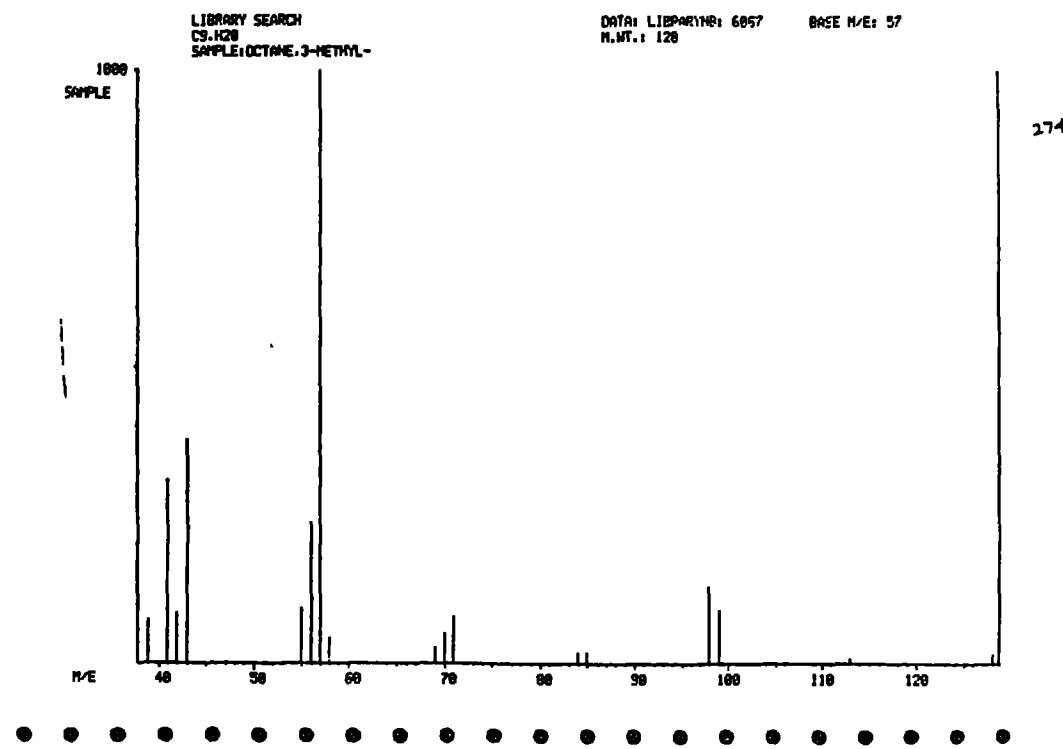


Figure 274. Mass spectrum of 3-methyloctane from computer library.

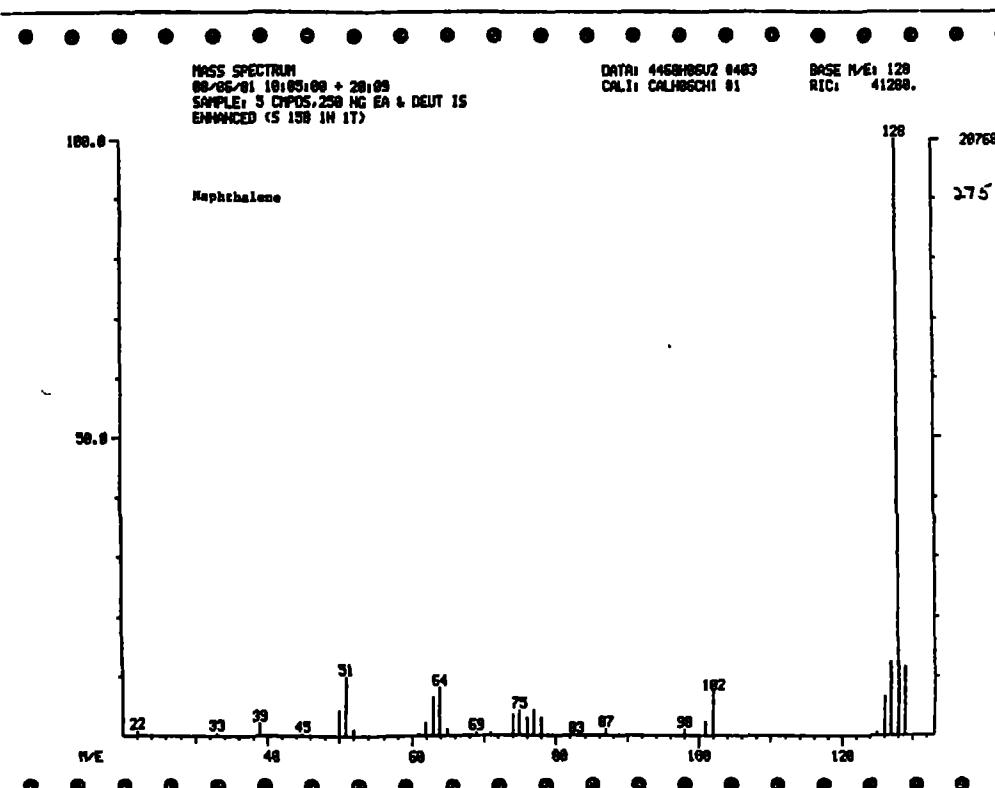


Figure 275. Mass spectrum of naphthalene from standard.

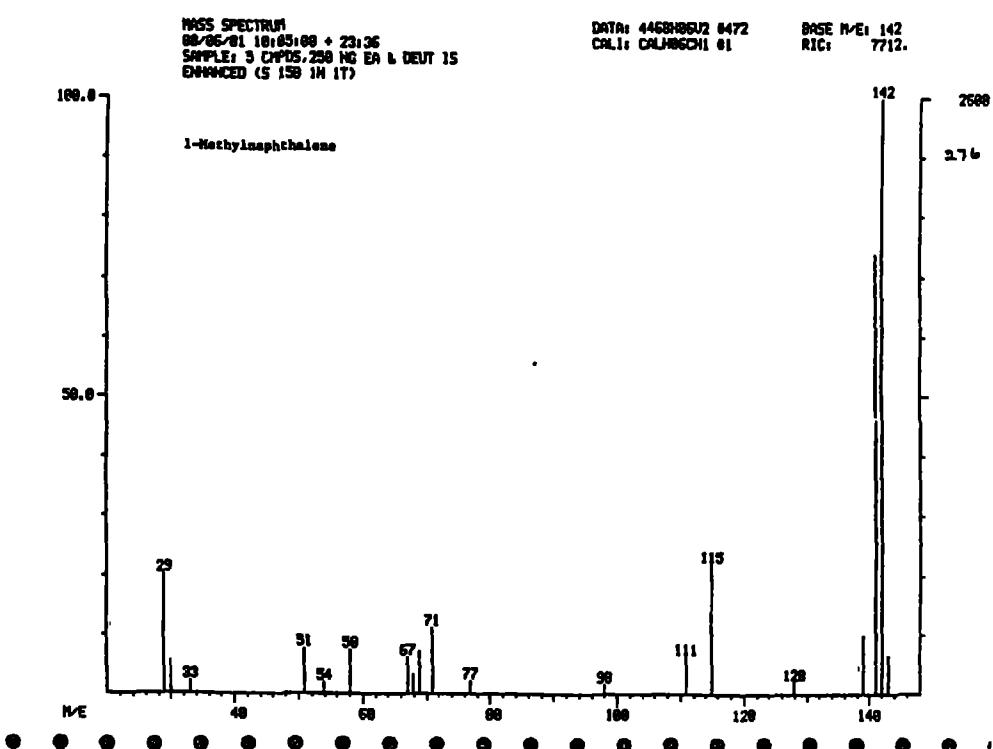


Figure 276. Mass spectrum of 1-methylnaphthalene from standard.

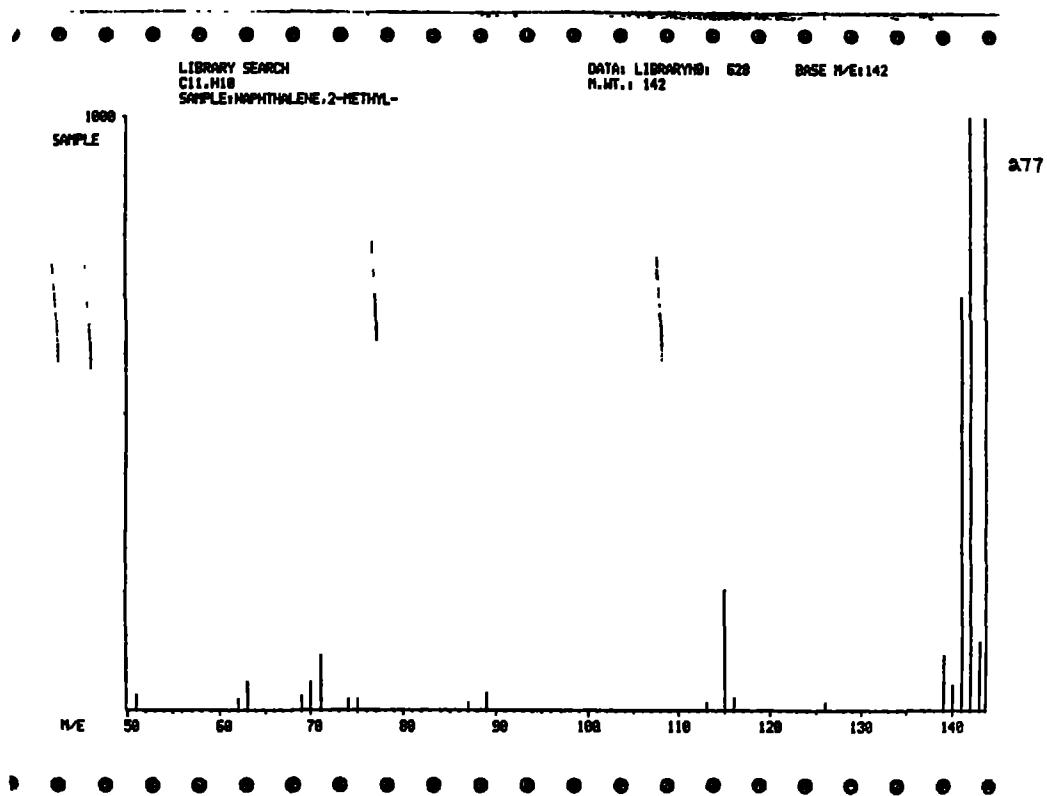


Figure 277. Mass spectrum of 2-methylnaphthalene from computer library.

APPENDIX

CHAIN-OF-CUSTODY FORMS

CHAIN OF CUSTODY RECORD

CHAIN OF CUSTODY RECORD

Project No.: 4468-L21
V.S (S) Samplers:
(Signature) Ronald J Wolf

Sample No. B134 54-54½

Field No. 810562 EO.

CHAIN OF CUSTODY RECORD

Project No.:	4468-L21 USGS	Samplers: (Signature)	Ronald J. Wolf
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Sample No. B134 25 feet

Field No. 81056

CHAIN OF CUSTODY RECORD

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI

CHAIN OF CUSTODY RECORD

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI

CHAIN OF CUSTODY RECORD

Project No.:	4468-L21 USGS	Samplers: (Signature)	Ronald J. Wolf
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Sample No. B130 24 feet

Field No. 81055

CHAIN OF CUSTODY RECORD

Project No.:	44168-L21 USGS	Samplers: (Signature)
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Sample No. B129 6½-7 feet

Field No. 81055-

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110



CHAIN OF CUSTODY RECORD

Project No.:	4468-L21 USGS	Samplers: (Signature)	Ronald J. Wolf
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Sample No. B127 10 feet

Field No. — 810556 —

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI

CHAIN OF CUSTODY RECORD

Project No.: 4468-L21 U.S.G.S.	Samplers: (Signature) <u>Ronald J. Wolf</u>
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Sample No. B126 15 feet

Field No. 8105--

CHAIN OF CUSTODY RECORD

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI

CHAIN OF CUSTODY RECORD

Project No.: 4468-L21	Samplers: (Signature) Gregory B. Justia
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Sample No. W 13

Field No. 81055

CHAIN OF CUSTODY RECORD

Project No.:	4468-L21 USGS	Samplers: (Signature)
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Sample No. SIP #15

Field No. 81059

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI

CHAIN OF CUSTODY RECORD

Project No.: 4468-L21
USGS Samplers:
(Signature) Gregory B. Justin

Sample No. SLP #4

Field No. 8105c

CHAIN OF CUSTODY RECORD

Project No.: 44168-L21 USGS	Samplers: (Signature) Gregory B. Justen
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Sample No. P 14

Field No. — 8105cc —

CHAIN OF CUSTODY RECORD

CHAIN OF CUSTODY RECORD

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI 

CHAIN OF CUSTODY RECORD

Project No.: 4468-L21 USGS	Samplers: (Signature) Gregory B. Justus
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Sample No. WEDWOOD NURSING HOME

Field No. — 810553 —

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI

CHAIN OF CUSTODY RECORD

Project No.:	4468-L21 USGS	Samplers: (Signature)
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Sample No. EDINA #16

Field No. 81055

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI

CHAIN OF CUSTODY RECORD

Project No.: 4468-L21 USGS	Samplers: (Signature) Gregory O. Justus
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Sample No. EDINA #6

Field No. 81055

CHAIN OF CUSTODY RECORD

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI 

CHAIN OF CUSTODY RECORD

CHAIN OF CUSTODY RECORD

Project No.: 4468-L21
Samplers: (Signature) Gregory B. Justus

Sample No. EDINA #2

Field No. 810550

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI

CHAIN OF CUSTODY RECORD

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110



CHAIN OF CUSTODY RECORD

Project No.: USGS	Samplers: (Signature) Gregory B. Justen
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Sample No. SLP #10

Field No. 81054

CHAIN OF CUSTODY RECORD

Project No.: USGS	Samplers: (Signature) Gregory B. Justia
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Sample No. SCP # 8

Field No. 810543

**Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110**



CHAIN OF CUSTODY RECORD

**Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110**

MRI

CHAIN OF CUSTODY RECORD

Project No.:	USGS	Samplers: (Signature)	Gregory B. Juster
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Sample No. SLP #5

Field No. 8105

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI 

CHAIN OF CUSTODY RECORD

Project No.: USGS Samplers: (Signature) Gregory B. Justus

Sample No. MTKA # 14

Field No. 810512

**Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110**

MRI

CHAIN OF CUSTODY RECORD

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI

CHAIN OF CUSTODY RECORD

Project No.: USGS	Samplers: (Signature) <i>Gregory B. Justen</i>
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Sample No. MJKA #12

Field No. — 81051c —

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110



CHAIN OF CUSTODY RECORD

Project No.:	1565	Samplers: (Signature)	Gregory B Justus
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Sample No. MTKA # 11

Field No. 8105

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI 

CHAIN OF CUSTODY RECORD

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI

CHAIN OF CUSTODY RECORD

Project No.:	USGS	Samplers: (Signature)	Henry B. Justus
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Sample No. HOPKINS #1

Field No. 810537

**Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110**

MRI 

CHAIN OF CUSTODY RECORD

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI

CHAIN OF CUSTODY RECORD

Project No.: 4468-L21
Samplers: (Signature) *Gregory B. Quasten*

Sample No. Norris Milk

Field No. 81053

**Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110**

MRI

CHAIN OF CUSTODY RECORD

Project No.: 4468-L21 USGS	Samplers: (Signature) Gregory B. Justen
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Sample No. FLAME INDUSTRIES

Field No. 81053⁴

CHAIN OF CUSTODY RECORD

Project No.:	4468-L21 USGS	Samplers: (Signature)
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Sample No. ETEL HOSP.

Field No. 810533

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI

CHAIN OF CUSTODY RECORD

Project No.: 4468-L21
Samplers: USGS
(Signature) Gregory B. Justus

Sample No. W 38

Field No. 819532

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI 

CHAIN OF CUSTODY RECORD

Project No.:	USGS 4468-21	Samplers: (Signature)	Gregory B. Juster
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Sample No. DAYTONS #3

Field No. 810531

**Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110**



CHAIN OF CUSTODY RECORD

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI 

CHAIN OF CUSTODY RECORD

**Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110**

MRI

CHAIN OF CUSTODY RECORD

Project No.: USGS 4468-L21	Samplers: (Signature) <i>Gregory B. Quater</i>
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Sample No. Old SLP #1

Field No. 81052

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI 

CHAIN OF CUSTODY RECORD

**Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110**



CHAIN OF CUSTODY RECORD

Project No.: 4468-L21 USGS	Samplers: (Signature) <i>Gregory B. Justin</i>
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Sample No. NAT LEAD

Field No. 210500

CHAIN OF CUSTODY RECORD

Project No.: 4468-L21 Samplers:
(Signature) *Gregory B. Justin*

Sample No. MN Rubber

Field No. 81052c

**Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110**

MRI

CHAIN OF CUSTODY RECORD

Project No.: 4468-L21	Samplers: (Signature) Gregory B. Justin
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Sample No. SLP #6

Field No. — 81052. —

**Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110**



CHAIN OF CUSTODY RECORD

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI

CHAIN OF CUSTODY RECORD

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110



CHAIN OF CUSTODY RECORD

Project No.: 4468-L21	Samplers: (Signature) <i>Gregory B. Juster</i>
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Sample No. SLP #4

Field No. 81052

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI

CHAIN OF CUSTODY RECORD

CHAIN OF CUSTODY RECORD

**Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110**

MRI

CHAIN OF CUSTODY RECORD

Project No.: USGS 4468-21	Samplers: (Signature) Gregory B. Juster
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Sample No. Prudential Wall #2

Field No. 810513

CHAIN OF CUSTODY RECORD

Project No.: USGS 4468-L2	Samplers: (Signature) Gregory B. Justia
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Sample No. Meadowbrook Golf Course

Field No. 810517

CHAIN OF CUSTODY RECORD

Project No.: 4468-L21 USGS	Samplers: (Signature) Gregor B. Juster
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Sample No. W13 (445615093220901)

Field No. — 810516 —

**Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110**



CHAIN OF CUSTODY RECORD

Project No.: USGS 4468-L21	Samplers: (Signature) <i>Gregory B. Justin</i>
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Sample No. Minnesota Rubber

Field No. 310515

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

CHAIN OF CUSTODY RECORD

Project No.: 4468-L21	Samplers: (Signature)
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Sample No. SLP 6

810514

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

CHAIN OF CUSTODY RECORD

Project No.: 4468-L21 Samplers:
(Signature) James F. Ruhl

Sample No. SLP5

-810513

**Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110**

MRI

CHAIN OF CUSTODY RECORD

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI

CHAIN OF CUSTODY RECORD

CHAIN OF CUSTODY RECORD

Project No.: 4468-L21 Samplers:
(Signature) Gregory B. Justin

Sample No. W 117

Field No. - 810510 -

CHAIN OF CUSTODY RECORD

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI

CHAIN OF CUSTODY RECORD

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI

CHAIN OF CUSTODY RECORD

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

MRI

CHAIN OF CUSTODY RECORD

Project No.: 4468-L21	Samplers: (Signature) Gregory B. Justin
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Sample No. W 1

Field No. 810506